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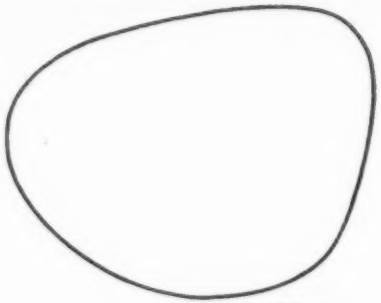

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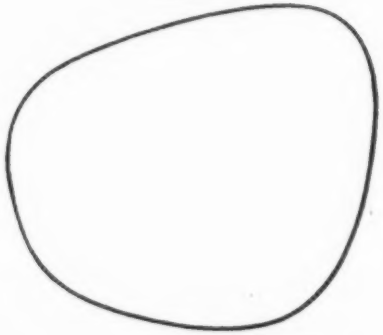

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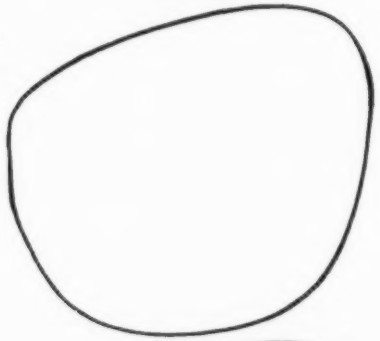

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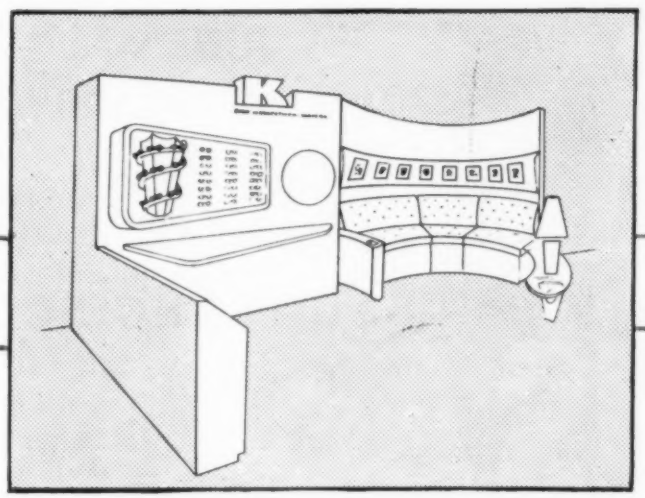

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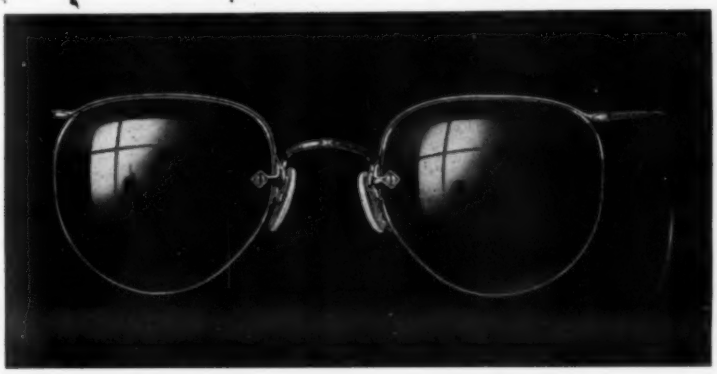

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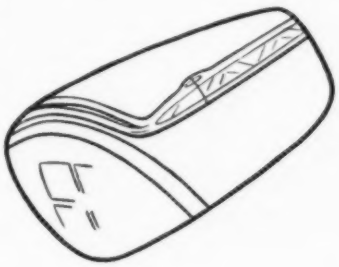

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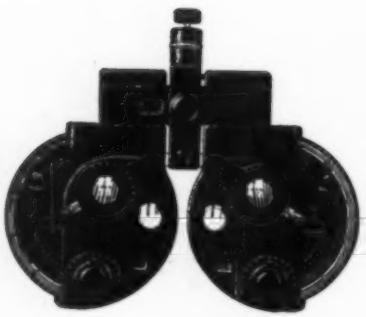

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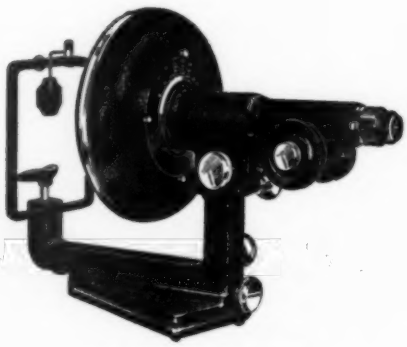

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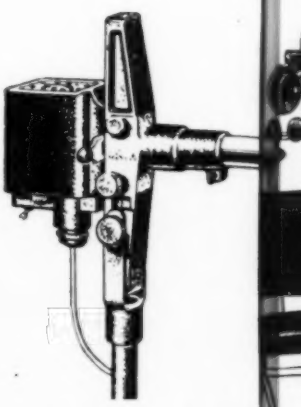

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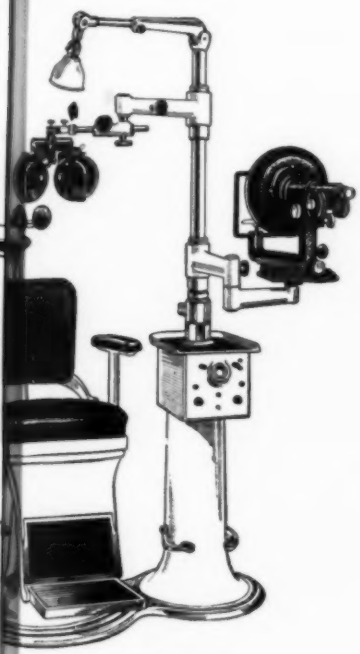

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Vol. 25 JUNE, 1948 No. 6

THE CORRECTION LENS*

Julius Neumueller†
Pennsylvania State College of Optometry
Philadelphia, Pennsylvania

PART I.

Preface.
The Optical System of the Eye.
Optical Defects of the Human Eye.
The Uncorrected Eye.
Correction Lens at the Primary Focus of the Eye.
Shifting the Correcting Lens.

PREFACE

From time to time, it seems necessary to restate the fundamental principles of any field of human endeavor. It is not uncommon that fundamental principles become diluted, distorted and forgotten in the course of new developments or in the attempt to substitute seemingly loftier aims and ideas for fundamental principles. This seems to have taken place in some quarters of optometry where it has become the custom to replace the consideration of fundamental optical principles with vague speculation of psychological nature. For some optometrists, this is an act of defense to hide their lack of mathematical discipline which makes matters worse as it introduces a tinge of dishonesty.

As the ultimate expression of our art or science and skill is represented by the correction lens, I have chosen this topic for my paper. I am well aware of the inadequacies of this presentation which, of necessity, is occasionally reduced to a table of contents but I hope that it may serve as an incentive to elaborate on its various parts in future papers.

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*The first of a series of four articles. Read before the annual meeting of the American Academy of Optometry, Chicago, Illinois, December 15, 1947. For publication in the June, 1948, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

†Optometrist, Fellow, American Academy of Optometry, Professor of Optometry.

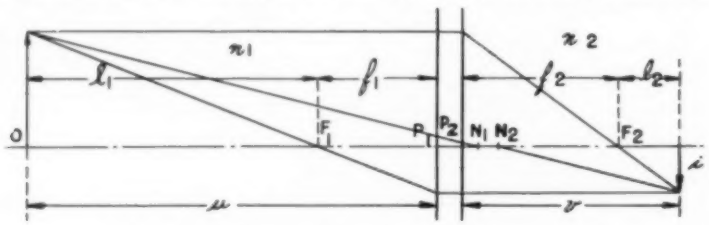
I am indebted to the American Optical Company for many of the finished drawings and photostats, as well as to Dr. Harold Simmerman for the production of the lantern slides and his willingness to read the paper in my stead.

THE OPTICAL SYSTEM OF THE HUMAN EYE

The human eye is an optical instrument. The best proof of this statement is the fact that its deficiencies are corrected by optical means in over 95 per cent of all cases. Some fundamental facts apply to all optical instruments and, therefore, also to the human eye. They must be considered when correcting the optical deficiencies of the human eye.

Imagery in the paraxial region of a symmetrical optical system is determined when the positions of the focal points, of one pair of conjugate points and the ratio of the indices of the first and last medium are known. Certain pairs of conjugate points or planes are more prominent than others. Gauss, a German mathematician, in 1841 chose two pairs of cardinal points to formulate his well known and famous system. (Figure 1.) Use of this system saves the labor of tracing each paraxial ray through every individual refractive or reflective surface, and reveals the fundamental relationship existing between object and image space.

The first pair of cardinal points, chosen by Gauss, are the principal planes for which the lateral magnification is unity. The primary principal plane is to be regarded as the end of the object space and the secondary principal plane as the beginning of the image space. The other pair of conjugate points chosen by Gauss are the nodal points related so that an incident ray directed to the primary nodal point will emerge



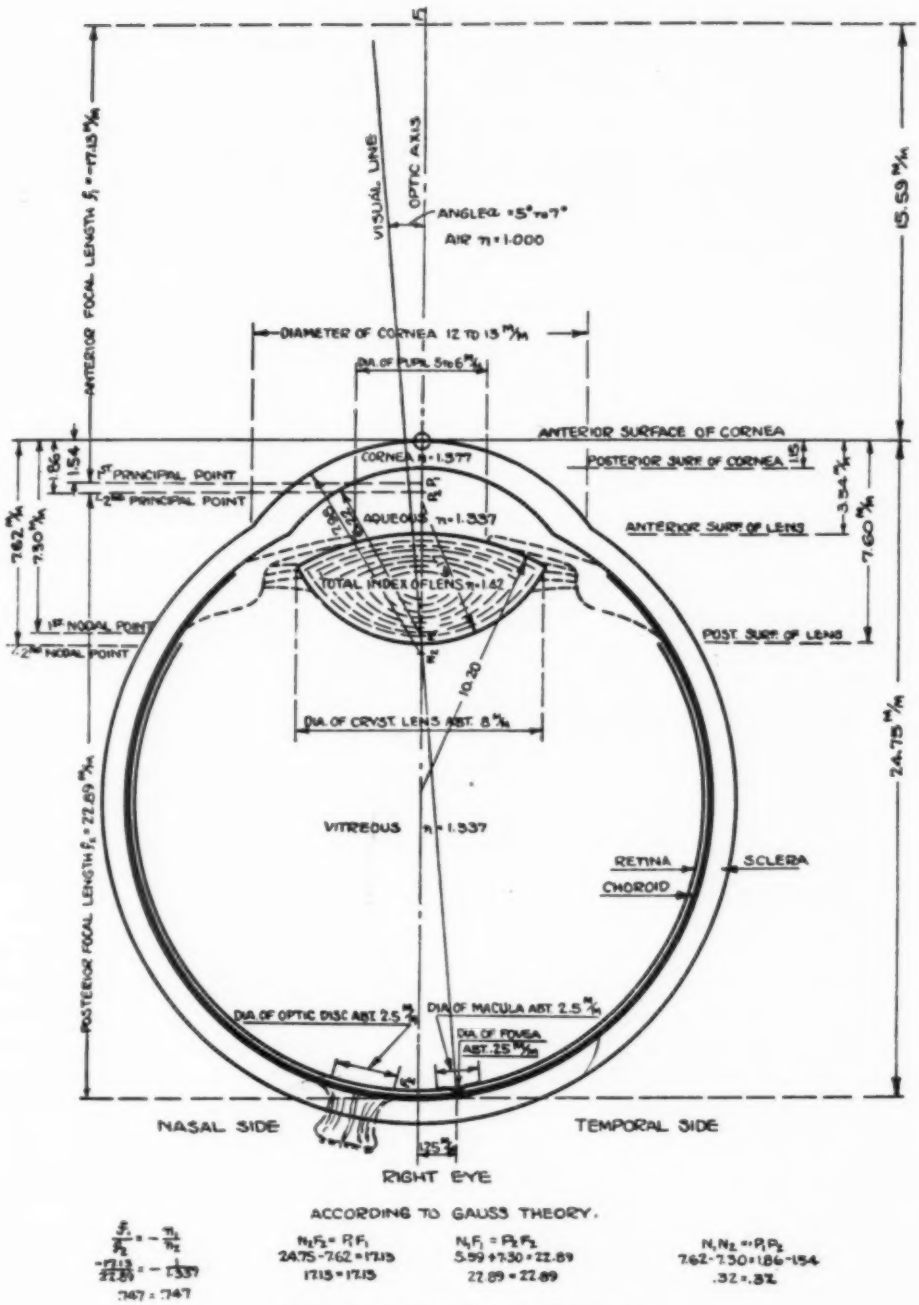
$P_1P_2 = N_1N_2$; $\frac{f_1}{f_2} = -\frac{n_1}{n_2}$; $N_1F_1 = -f_2$; $N_2F_2 = -f_1$;

$-\frac{n_1}{u} + \frac{n_2}{v} = \frac{n_2}{f_2} = -\frac{n_1}{f_1}$; $l_1 l_1 = f_1 f_2$;

$\frac{i}{o} = \frac{v}{n_2} \cdot \frac{n_1}{u}$; $\frac{i}{o} = -\frac{f_1}{l_1} = -\frac{l_2}{f_2}$

GAUSS' SYSTEM

Figure 1.



ACCORDING TO GAUSS THEORY.

$\frac{f_1}{f_2} = -\frac{n_1}{n_2}$

$\frac{-17.13}{22.89} = -\frac{1}{1.337}$

.747 = .747

$N_2F_2 = P_1F_1$

24.75 − 7.62 = 17.13

17.13 = 17.13

$N_1F_1 = P_2F_2$

5.59 + 7.30 = 22.89

22.89 = 22.89

$N_1N_2 = P_1P_2$

7.62 − 7.30 = 1.86 − 1.54

.32 = .32

Figure 2. Schematic Eye (Human).

from the secondary nodal point parallel to the incident ray. Because of this characteristic, the angle formed by the limiting rays to the object in the primary nodal plane equals that formed by the conjugate limiting rays to the image in the secondary nodal plane and expresses the angular size of the object or of the image. From Gauss' system certain fixed relationships follow between the locations of the six cardinal points: the two focal points, the two principal points and the two nodal points so that:

$$P_1\,F_1 = f_1\;;\quad P_2\,F_2 = f_2\;;\quad N_1\,N_2 = P_1\,P_2\;;$$

$$\frac{f_1}{f_2} = -\frac{n_1}{n_2}\;;\; N_1\,F_1 = -f_2\;;\quad N_2\,F_2 = -f_1\;;$$

$$-\frac{n_1}{u} + \frac{n_2}{v} = \frac{n_2}{f_2} = -\frac{n_1}{f_1}\;;$$

$$\frac{i}{o} = \frac{v}{n_2} \cdot \frac{n_1}{u}\;;$$

$$l_1\,l_2 = f_1\,f_2\;;$$

$$\frac{i}{o} = -\frac{f_1}{l_1} = -\frac{l_2}{f_2}\;;$$

where l_1 and l_2 are the object-and-image distances measured from the primary and secondary focal point respectively.

The mechanical and optical constants of the human eye have been determined by many investigators and Gauss' system was computed from these constants. It is possibly true that there is not one human eye that possesses the identical values set down by any of these investigators but undoubtedly the great majority of all human eyes have dimensions closely approaching these theoretical constants. Besides, we are not interested so much in the absolute values but rather in the relative changes which take place in uncorrected and corrected ametropia.

In 1923 I made a detailed drawing of the schematic human eye based upon the constants given by Tscherning. From this drawing The American Optical Company in 1937 struck a plate. The drawing contains the physical dimensions and the indices of refraction of the various media as well as the Gauss system replacing all the refracting surfaces of this schematic eye. Figure 2. The power of this eye would be 1.000 : 17.13 = 58.3D.

In order to simplify the constructions and computations concerning the formation of the retinal image, it is best to have the human eye represented by a single spherical refracting surface with a radius of 6 mm. separating air from index 4/3. Such an eye would have a power of

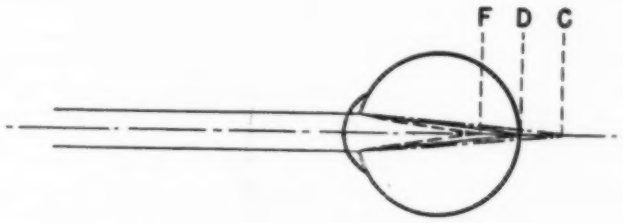
1,000 ÷ 18 = 55.5D. The Gauss system replacing this eye would be extremely simple as the two principal points would coincide with the pole of the surface and the two nodal points with its center of curvature.

OPTICAL DEFECTS OF THE HUMAN EYE

The human eye can be regarded as consisting of a series of centered spherical surfaces separating mediae of various indices. The disadvantage of the small fovea is offset by the motility of the eye. It is rotatable in all directions around a center located about 13 mm. behind the cornea. The formation of the retinal image, as well as the control of the intrinsic illumination is assisted by a reflexively operated diaphragm, the pupil.

Like any other optical system, the human eye has certain optical defects or aberrations. On account of the relatively small effective entrance pupil and the minuteness of the fovea, these aberrations of the unaided eye are not disturbing in uniocular vision. In binocular vision, the relative difference in size and shape of the retinal images can, and often does cause fusional disturbances.

Light of shorter wave lengths is refracted more than that of longer wave lengths. This causes chromatic aberration with blue light, coming to a shorter focus than the red. Figure 3.

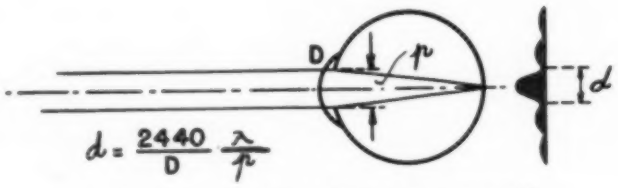


CHROMATIC ABERRATION

Figure 3.

The chromatic aberration of the eye for the C and F lines of Fraunhofer amounts to slightly more than one diopter. The so-called bichrome test, a subjective test for the spherical component of the correction, makes use of the chromatic aberration of the eye. Test objects are projected through properly selected red and green filters. By changing the lenses before the patient's eye until the projected images look equally black in the red and green field, the intermediate yellow light is focused on the retina of the assumedly unaccommodated eye.

Another defect due to the wave characteristics of light is diffraction. Figure 4.



DIFFRACTION [AIRY'S DISC.]

Figure 4.

A light point will be imaged by an optical system with a circular aperture, not as a point but as a small circular patch of light surrounded by rings of diminishing brightness. The central patch of light of the image is known as Airy's disk and its diameter is

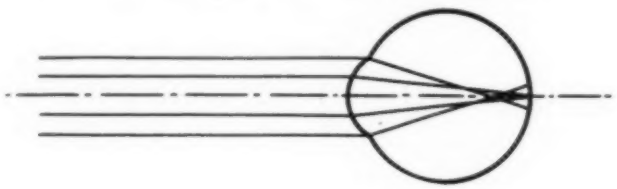
$$d = \frac{2440}{D} \frac{\lambda}{p}$$

where

D is the dioptric power of the eye
λ is the wave length of the incident light
p is the diameter of the pupil.

The diameter of Airy's disk is inversely proportional to the diameter of the pupil and with small pupils can exceed the diameter of a foveal cone, and thus reduce the definition of the retinal image.

Usually any centered spherical optical system shows a positive spherical aberration. Of a bundle of axially parallel rays, the peripheral ones come to a focus in front of the central ones. Figure 5.



SPHERICAL ABERRATION

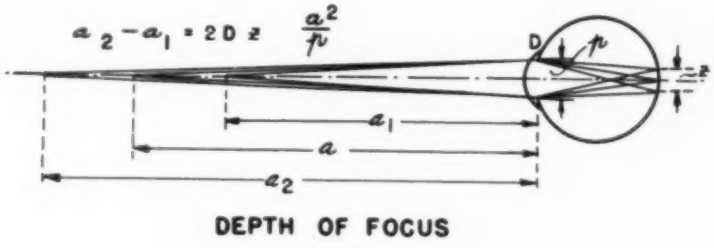
Figure 5.

This discrepancy in foci increases with the diameter of the pupil. Unless the spherical aberration of the eye is augmented by that of the

peripheral portion of the correction lens, it is of small concern.

Aberrations due to oblique incidence, such as coma and astigmatism, do not occur in the unaided eye as its visual and optical axes almost coincide for any direction of the gaze.

One characteristic of the human eye which cannot be called a defect is the depth of focus. Figure 6. This is a phenomenon well known to any photographer and depends on the power of the system, the diameter of the aperture and the size of the grain of the film. The grain of the human retina is not infinitely fine but, based upon a V.A. of 20/20, a retinal foveal unit has a diameter of .004 mm. Assuming a total absence of any disturbing aberration, a point object would cause a point image. This point image could increase to a patch of .004 mm. diameter without disturbing the sharpness of the image. Therefore, points in space farther or closer than the fixated point will be seen clearly without any change of focus as long as the size of the image point does not exceed that of the retinal unit.



DEPTH OF FOCUS

Figure 6.

The depth of focus extends farther beyond than within the fixation distance. The total extent is expressed by the formula

$$a_2 - a_1 = 2Dz\,\frac{a^2}{p};$$

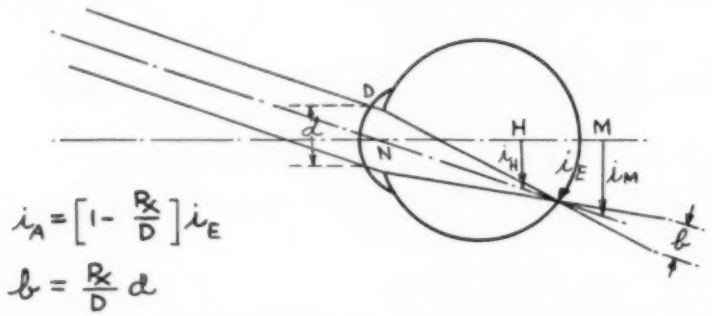
where a_2 and a_1 are the farthest and closest limits of the depth of focus.

D is the power of the eye
z is the size of the retinal unit
a is the distance of the fixation point
p is the diameter of the pupil.

The depth of focus then increases with the square of the distance of fixation and is inversely proportional to the diameter of the pupil. Old eyes with small pupils often simulate an unduly large range of accommodation due to this depth of focus.

THE UNCORRECTED EYE

An emmetropic eye, using no accommodation, will receive a clear retinal image of far-distant objects. The secondary focus will coincide with the retina. An ametropic eye is either relatively too short so that the secondary focus comes to fall behind the retina as in hyperopia, or too long so that the secondary focus is in front of the retina as in myopia. This discrepancy can be brought about by various causes, namely: the eye can actually be too short or too long having the same optical system as an emmetropic eye, or the eye may have the same physical length as the emmetropic eye but its power is weaker or stronger, either due to a change in curvature of one or more of its refracting surfaces or a change in index of one or more of its components. The relative change in optical imagery is the same regardless of the ametropia. In order to be able to consider these changes, we shall assume that ametropia is due only to an axial shortening or lengthening of the eye ball. Figure 7.



SIZE OF RETINAL IMAGE AND OF BLUR CIRCLE IN UNCORRECTED AMETROPIA

Figure 7.

The ametropic, unaccommodated eye will receive a blurred image because its focal plane does not coincide with the retina. Its image will be larger in the myopic eye and smaller in the hyperopic eye as compared with the image received by the unaccommodated emmetropic eye. The image size in the ametropic eye is expressed by:

$$i_A = \left[1 - \frac{R}{D}\right] i_E$$

and the diameter of the blur-circle is

$$b = \frac{R}{D} d$$

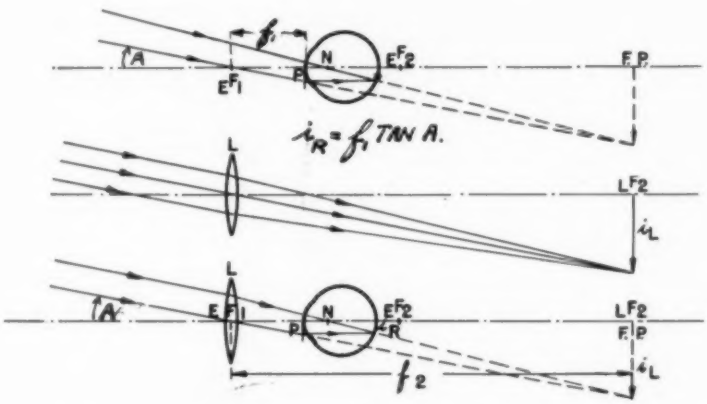
where R is the dioptric power of the correction lens

D is the dioptric power of the eye
d is the diameter of the pupil
iE is the image size in the emmetropic eye.

CORRECTION LENS AT PRIMARY FOCUS OF THE EYE

Certain conditions must be fulfilled in order that a sharp image may be received on the retina of the ametropic, unaccommodated eye. For a myopic eye, the object should be located in front of the eye, and for a hyperopic eye it should be located behind the eye. This real or virtual object plane is called the far-point plane of the ametropic eye and is conjugate to the retina in reference to the optical system of the eye. The function of the correcting lens is then to image far-distant objects in the far-point plane of the eye. These images will serve as real or virtual objects for the eye to be imaged by its optical system on the retina.

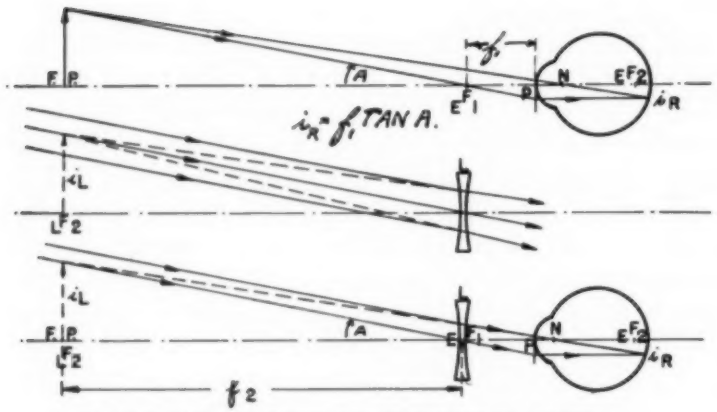
As far-distant objects will be imaged in the focal plane of the correction lens, the following rule is obvious, namely: "The focal plane of the correction lens must coincide with the far-point plane of the ametropic eye." Figure 8 and Figure 9.



R_x LENS AND FAR POINT RELATIONSHIP IN HYPEROPIA

Figure 8.

The next question to be considered is "How is the size of the retinal image affected by the correction lens?" An infinitely thin correction lens applied at the primary focus of the ametropic eye will not affect the lateral size of the retinal image of distant objects. Whether



R_X LENS AND FAR POINT RELATIONSHIP IN MYOPIA

Figure 9.

the eye is ametropic or emmetropic, the lateral size of the retinal image of a distant object is:

$$i = f_1 \tan a$$

Where f_1 is the anterior focal length of the eye

a is the angle enclosed by the limiting rays to the object.

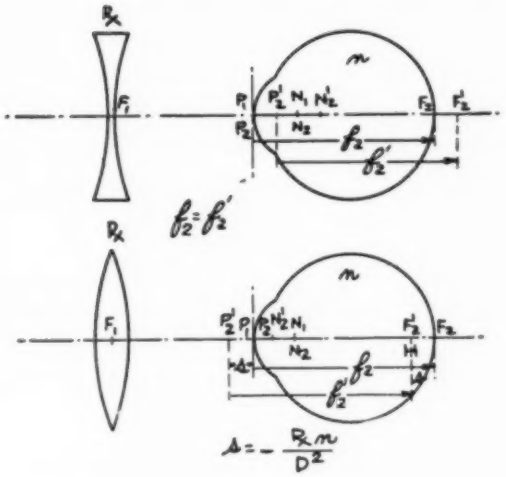
The only effect the correcting lens would have, when applied at the primary focal plane of the eye, is to shift the original image and the secondary cardinal points of the eye fore and aft in an axial direction. This shift is equal to:

$$s = -\frac{R_1 n}{D^2}$$

where R_1 is the power of the correction lens
D is the power of the eye
n is the index of the vitreous.

This shift amounts to the change in length of the eye in axial ametropia. Figure 10.

Assuming such ideal conditions as an infinitely thin correction lens applied at the anterior focus of the eye, the lateral retinal images in ametropia and emmetropia are equal in size. If no disarrangement of the retinal units has taken place with ametropia, then the subjective impressions should also be identical. Usually the hyperope will report that

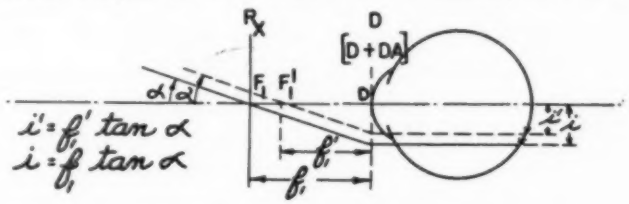


THE CORRECTION LENS APPLIED AT F_1 OF THE EYE DISPLACES THE SECONDARY CARDINAL POINTS BY THE AMOUNT OF THE RETINAL SHIFT

Figure 10.

the correction lens magnifies. This can be explained by the fact that the uncorrected hyperope may partially or fully overcome his error by means of accommodation. By so doing, he increases the power of his eye and shortens its focus, thus diminishing the size of the retinal image. When correction is applied, the accommodation can be relaxed and the retinal image now becomes relatively larger.

A test lens applied at the anterior focus of the eye, but of such power as to cause accommodation, causes the retinal image to diminish in size. The reason is that the power of the optical system of the human eye is increased by the amount of the accommodation and therefore its anterior focal length is shortened. The limiting ray is now incident

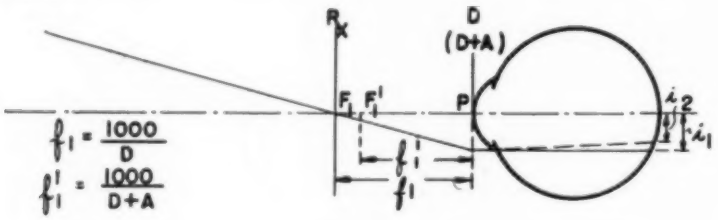


i' = RETINAL IMAGE IN THE ACCOMMODATED HYPEROPIC EYE
i = RETINAL IMAGE IN THE CORRECTED HYPEROPIC EYE

Figure 11.

outside the anterior focal point and, therefore, the refracted conjugate ray converges towards the axis. Figure 11.

The corrected myope will notice a diminution of size due to the reduction of the larger but blurred retinal image of the uncorrected eye to the sharp but smaller image of the corrected eye. Figure 12. Refer also to Figure 7.



A TEST LENS CAUSING ACCOMMODATION

REDUCES THE SIZE OF THE RETINAL IMAGE

Figure 12.

Many cases of corrected anisometropia show a relative difference in the size of the retinal images so that the less myopic or more hyperopic eye gives the subjective impression of a larger image. For a purely axial ametropia, this could only be explained by a proportional crowding of the retinal units in axial hyperopia and a spreading of these units in axial myopia. Another explanation may be found in a change of the dioptric power of the eye and as the corneal power is the highest component an investigation into a correlation of corneal curvatures and aniseikonia would be of interest.

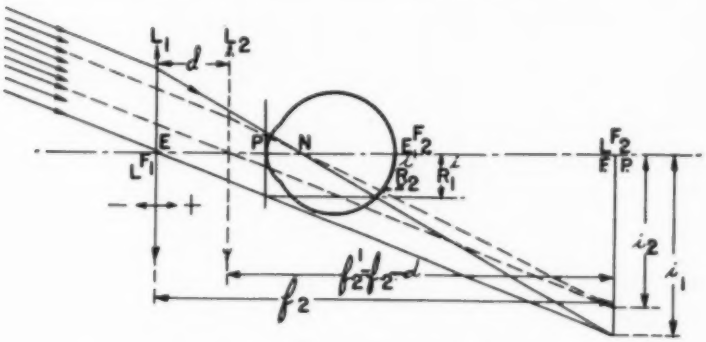
SHIFTING THE CORRECTING LENS

The position of the far point is inherent to the eye. As the focus of the correcting lens must always coincide with the far point, therefore, the focal length and power of the correction lens must change with its position. To test with a lens in one position and to apply the correcting lens at another position can lead to serious discrepancies, particularly when higher powers are involved. Figure 13. When a plus lens is moved away from the eye, its effectivity is increased just as if more plus power were added to it. On the other hand, the effectivity of a minus lens is decreased when moving it away, again giving the effect of added plus power. In order to restore coincidence of the far point and the focus of the correcting lens, the power of the latter must be modified when its position is changed. If L_1 is the power of the lens in the first position

and the lens is shifted d mm. (minus when away from the eye), then the power L_2 in the new position is

$$L_2 = \frac{L_1}{1\text{-}d\ L_1} \approx L_1 + d\ L_1^2$$

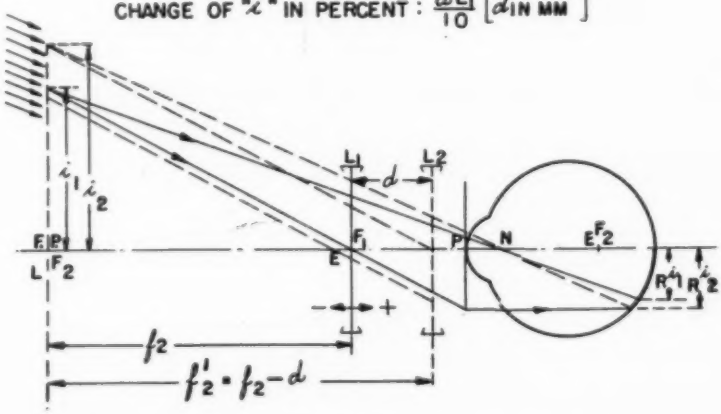
POWER $L_2 = \frac{L_1}{1-dL_1} \approx L_1 + dL_1^2$ [d IN METERS]
RETINAL IMAGE SIZE $R^{i}2 = [1 + dL_1]\ R^{i}1$
CHANGE OF "i" IN PERCENT: $\frac{dL_1}{10}$ [d IN MM.]



INFLUENCE OF SHIFT OF R_x LENS IN HYPEROPIA

Figure 13.

POWER $L_2 = \frac{L_1}{1-dL_1} = L_1 + dL_1^2$ [d IN METERS]
RETINAL IMAGE SIZE $R^{i}2 = [1 + dL_1]\ R^{i}1$
CHANGE OF "i" IN PERCENT: $\frac{dL_1}{10}$ [d IN MM]



INFLUENCE OF SHIFT OF R_x LENS IN MYOPIA

Figure 14.

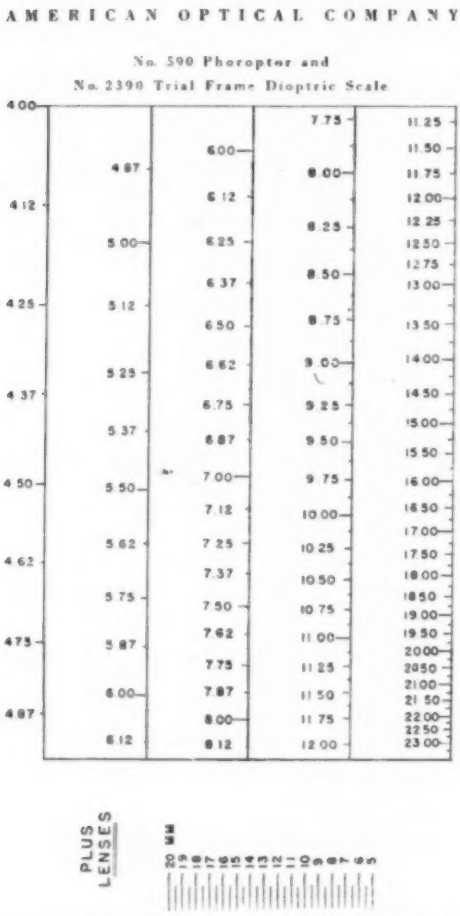


Figure 15. Chart reduced in size and showing only slide for convex lenses.

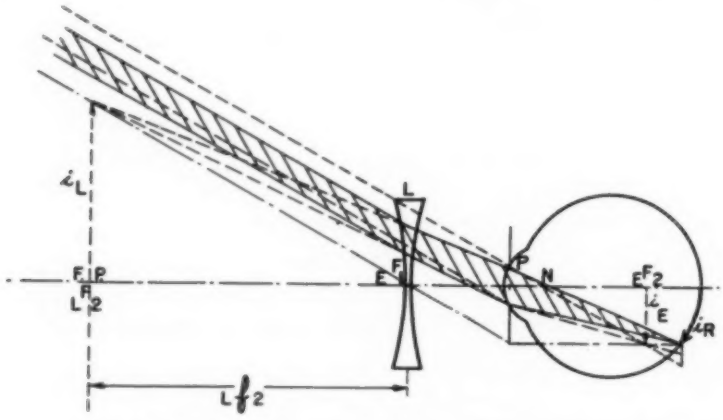


Figure 16.

Dr. Paul Boeder of the Bureau of Visual Science of The American Optical Company has designed a very ingenious and simple device to compute the power of any lens when shifted from its original position. Figures 14 and 15.

A change of position of the lens also affects the size of the retinal image in the following manner:

$$_{R}i_{2} = \left[1 + d\ L_1\right]\ _{R}i_{1}$$

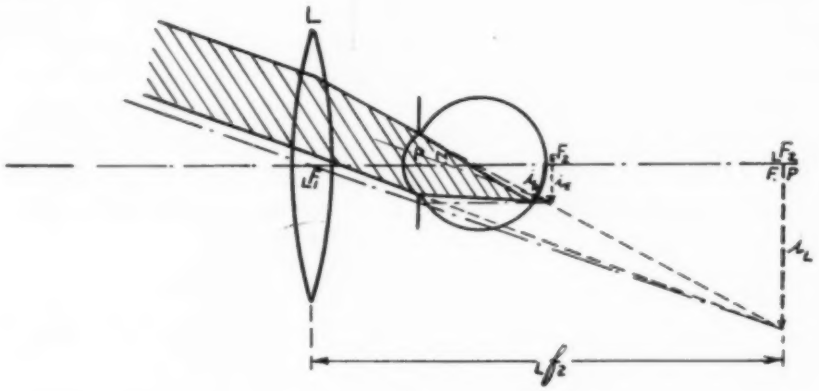
or the change in per cent is:

$$\frac{d\ L_1}{10}\ \% \text{ (d in mm.)}$$

where:

$_{R}i_1$ is the size of the retinal image with the lens at L_1
$_{R}i_2$ is the size of the retinal image with the lens at L_2
d the amount of the shift in meters
L_1 the power of the correcting lens.

Of main interest is the pupillary bundle of incident rays. Their course through the correction lens and the eye to the final retinal image is shown in Figures 16 and 17. Again, infinitely thin lenses are assumed to be applied in the primary focal plane of the axially ametropic eye. The schematic drawings again show that the lateral size of the retinal images are alike: they also show the prismatic effect of the lenses upon the peripherally incident rays and their diverging respectively converging power.



PUPILLARY BUNDLE OF RAYS IN CORRECTED HYPEROPIA

Figure 17.

[Part Two of this paper will appear in the July issue.]

FACTORS CONCERNING THE PRESCRIPTION AND USE OF TELESCOPIC SPECTACLES*‡

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A. INTRODUCTION

It is commonly known that there is considerable variation of opinion as to the percentage of patients having subnormal vision who can be given satisfactory aid with telescopic spectacles.** The essential causes for this variation are two-fold: first, lack of understanding of the optical characteristics of telescopic spectacles and the requirements which must be met in the examination for telescopic aid and in fitting and use of the spectacles; second, inadequate insight as to the psychological factors of patients with subnormal vision who attempt to use optical aids. Since a failure to understand these factors oftentimes results in unsatisfactory aid being given to a patient with subnormal vision, careful consideration needs to be given to them.

B. OPTICAL FACTORS

Requirements in Design

First of all, it is necessary to realize that there are many requirements which have had to be met in the design of telescopic spectacles. In fact, the requirements are so numerous, that the designer is permitted very little freedom.

What are the requirements? The investigator, Levy, in a communication in the British Journal of Ophthalmology considered them in detail. He[7] pointed out that the magnification of the units is roughly fixed, since minimum magnifications must be provided to adequately aid individuals with different amounts of subnormal vision. The spectacles are required to have a relatively large exit pupil enabling the wearer to use the full aperture of his pupils. In order to reduce light-loss to a minimum, the number of air-glass surfaces as well as the thicknesses

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**An individual is said to have subnormal vision if when fully corrected for refractive errors with spectacles his visual acuity is no less than 20/200 nor better than 20/70 wth either eye.

‡Authors' Abstract, page 274.

of the lenses have to be kept as small as possible. The spectacles must also have a large field of view. Of course, the field has to be free from aberrations and distortions. A further requirement of the spectacles is that the image has to be erect.

In addition to these numerous optical factors, various human factors likewise have to be given careful consideration. The spectacles have to be light in weight so that they can be comfortably worn. Also, it is desirable that they present a pleasing appearance and do not attract undue attention. In order to minimize the changes in head posture required when the spectacles are worn, the telescopic components have to be located so that their optic axes will be coincident with the lines of sight when the head and eyes are in the straight forward or reading position.

The form of the telescope selected is invariably Galilean; that it to say, a telescope consisting essentially of a positive objective and a negative eyepiece. The principal reason underlying this choice is the fact that the telescope gives an erect image without the introduction of an auxiliary erecting system. Furthermore, the over-all length is considerably less in a telescope which requires a negative eyepiece compared to one requiring a positive eyepiece. This is especially important in regard to the cosmetic appearance of the telescopic unit. Also, the combination of positive and negative lens in the Galilean telescope is advantageous in securing a moderately flat field free from astigmatism.

It should be apparent now that the optical designer has very little freedom of choice. In fact, the over-all requirements of a telescopic spectacle are so stringent that compromises of either or both the optical

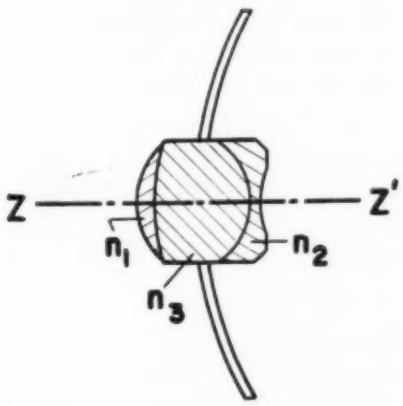

Figure 1. Univis one piece telescopic spectacle adjusted for distant vision and mounted in a carrier lens.

and human factors have to be made in the design of a particular unit. As a consequence, a particular design usually can best be identified by the adherence made to certain requirements. For example, in the all-glass telescopic spectacle, manufactured by The Univis Lens Company, the two factors, optical performance and appearance, are considered of utmost importance. In order to provide a unit which would be the least objectionable in appearance, the interspace between the objective and eyelens is composed of glass. The objective, the lens between the objective and eyelens and the eyelens itself are fused together so as to form a single unit of glass as illustrated in Figure 1.

Position of Entrance Pupil

The various requirements which have to be met in the design of telescopic spectacles produce certain limitations with regard to their use. One of these is that the pupil of the eye is the real exit pupil of the system composed of the telescopic unit and the eye. Figure 2. The en-

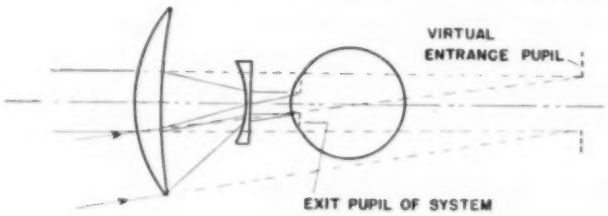

Figure 2. A Galilean telescope mounted before an eye. The exit pupil of the system composed of the telescope and the eye is the real pupil of the eye. The virtual image of the real pupil is the entrance pupil and it is located a distance behind the eye.

trance pupil of the system is the vertical image of the real exit pupil formed by the telescopic unit. This enforced position of the exit pupil necessitates eccentric passage of the oblique rays of a large field through the system. Since the means of controlling the aberrations are so limited, it is very difficult to correct the oblique rays. As a consequence, the center of the field is always found to be better corrected than the periphery. These factors make it imperative that a spectacle be accurately aligned before an eye in order to provide the best possible resolution.

Effective Power

Another factor which has to be given careful consideration in the use of telescopic spectacles is that the effective power of the telescope is the same as the effective power of the lenses required for the correction of an ametropia. It is well known that an ametropic unaccommodated eye is corrected only when the secondary focus of a correcting lens coin-

cides with the far point of the eye. If a telescopic unit of the same effective power as the correcting lens is employed, it has to be placed at the same distance in front of the eyes in order to correct the ametropia.

If a telescopic unit of positive power has a shorter or longer eyewire distance than the correcting lens, the unaccommodated eye will be under- and over-corrected, respectively. Conversely, if the telescopic unit is of negative power, the employment of a shorter or longer eyewire distance than the lens system will cause the unaccommodated eye to be over- and under-corrected, respectively.

Individuals with subnormal vision often require high refractive corrections in order to obtain the best possible distance correction. When this finding is considered with the fact that telescopic units are very frequently mounted close to the eye, the importance of changes in effective power for different vertex distances becomes apparent.

Role of Distance of Fixation

It is commonly known that telescopic spectacles are frequently employed for near visual tasks. When this is done, an auxiliary reading lens is mounted in front of the objective. The object of this auxiliary lens is to permit the use of the spectacles for near visual tasks without the employment of an abnormal amount of accommodation. The power of the reading lens is variable and usually is no less than 4.00 D. Reading additions of this magnitude enable the user to profit by the increase in angular size of the object due to a small distance of fixation.

It is to be noted, however, that whenever telescopic spectacles with reading additions are employed there is an increase in the demands on accommodation produced by changes in the distance of fixation relative to those encountered without a telescopic unit. For a given change in the distance of fixation, these demands are a function of the power of the reading addition, the power of the objective of the telescope and the magnification. Likewise, if the distance of fixation is greater or less than the focal length of the reading addition, the telescopic unit has positive or negative power, respectively. For these reasons, it is necessary that those who use telescopic spectacles for near visual tasks employ a fixed distance of fixation equal to, or less than the focal length of the reading addition.

C. EXAMINATION AND FITTING

In order to provide an adequate examination for telescopic spectacles, certain procedures need to be followed.[4] These will be discussed in the description of the following recommended routine for testing an in-

dividual with subnormal vision for telescopic spectacles. The equipment needed for the test is as follows:

1. A sturdy trial frame.*
2. A standard trial case of testing lenses.
3. A testing set containing several afocal units of different magnification with suitable reading caps.**

First of all, a thorough examination is made to ascertain the extent of an ametropia. By this means the patient's best distance correction is determined. After this correction has been found, it is placed in the back

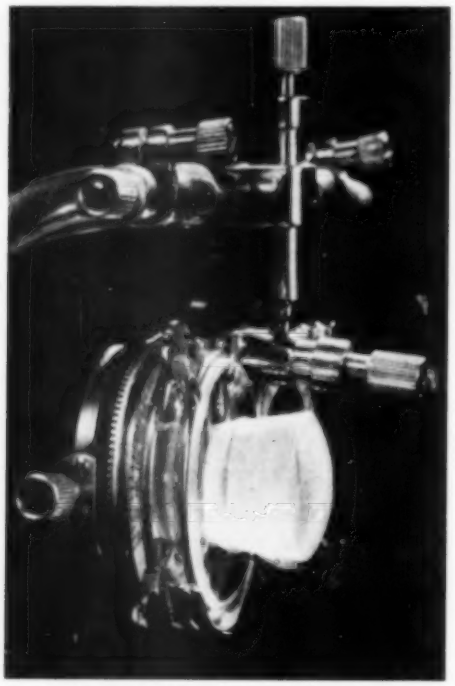

Figure 3. Testing unit in place.

cells of the trial frame. A 1.5X telescopic distance unit, Figure 3, is then placed into the anterior cell of the trial frame, and the latter is then adjusted so that the center of the pupil corresponds to the optic axis of the unit. The next step is to rack the cell unit laterally and vertically

*A trial frame similar to the one manufactured by the Bausch & Lomb Optical Company would be considered adequate.

**Two telescopic trial sets are available at the present time in the United States. One is manufactured by The Kollmorgen Optical Company, and the other by The Univis Lens Company. Although either set would be adequate for use in an examination, the telescopic units available in the Univis testing set will be used in the testing routine to be described.

to see if any improvement is evidenced, and to note the exact P.D. at which the vision is reported "best."

The test is then repeated with the 2.0X unit, in order to determine if there is a significant improvement in vision. Generally, there will be with higher magnification. It is then a matter of judgment on the part of the practitioner as to which unit is prescribed. As the size of field decreases with increase of magnification, it obviously is important to provide the smallest amount of magnification. After the best magnification has been determined, refine the distance prescription by rotating the axis of the cylinder and by varying the sphere.

Upon determining the best possible distance prescription, leave the assembly in position and present a reading card to the patient. A plus 4.00 sphere is then selected from the trial case and held in front of, and against the objective surface of the telescopic unit. By increasing the power of the sphere one can arrive subjectively at the best possible reading power. Since the reading distance varies inversely with the reading addition, the weakest addition with which the patient can have satisfactory near vision is prescribed.

Writing the Prescription

First, one has to determine whether the telescopic unit or units are to be worn for distance and reading or for reading only. If for the latter, the exact reading distance has to be measured. This is easily done as the depth of focus is small for this type of corrective lens at near. The exact distance P.D. must also be known. One can then proceed to write the prescription in the usual fashion. The best possible distance prescription is prescribed and one needs to indicate whether it is to be combined with either the 1.5X or 2.0X unit. Furthermore, the power of the reading addition has to be stated.

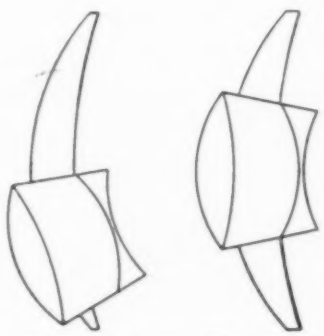

Figure 4. (Left). Telescopic near vision. (Right). Telescopic distance vision.

Fitting and Adjusting

As stated previously, the unfortunate location of the entrance pupil of the system composed of the telescopic unit and the eye necessitates an accurate adjustment of the telescope when it is mounted in front of the eye. To secure such an adjustment a frame with adjustable pads is recommended. This recommendation applies to telescopic units consisting of air as well as glass interspace between the objective and eyelens.

All-glass telescopic units are usually mounted in a carrier ophthalmic lens having the necessary power to correct a refractive error, Figure 4, (Schematic). The apertures for these units can be drilled at any desired angle and location. Consequently, the position of such units when used for either distance or near vision can be accurately controlled.

The Finished Spectacles

In an all-glass telescopic spectacle the carrier lens will usually have the patient's distance prescription ground into it. This makes it possible

Figure 5. Reading cap affixed to unit.

for a patient to utilize the carrier area for marginal unmagnified vision by a movement of the head. The prescription of such a spectacle is also ground on a small lens and cemented to the ocular surface of the unit.

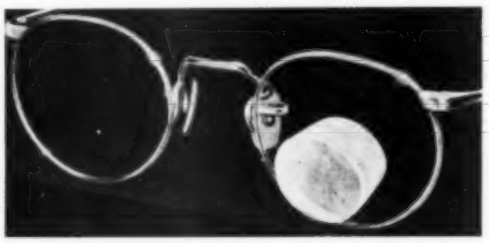

Figure 6. Reading unit.

This lens can be changed with little expense if and when such change is indicated.

If the telescope is an all-glass unit, a small plastic cap in the distance position with the reading aid in it is furnished and it can be snapped into place when the patient desires to read. This is illustrated in Figure 5. If the unit is placed in the reading position, the reading addition can be permanently ground into the unit, Figure 6, although the use of a reading cap is more desirable. One or more reading caps with varying powers are practical for different reading distances.

When to Use Telescopic Spectacles Binocularly

Telescopic spectacles may be prescribed binocularly for distance vision in any case where the patient has fusion and not too great a difference in acuity between the two eyes. It is not recommended that telescopic spectacles be used binocularly for reading unless the addition for near is less than plus 4.00 diopters. It appears that too great a convergence effort is necessary and binocular reading has not been successful. As a rule, therefore, telescopic spectacles worn binocularly for distance, should be worn monocularly for near. An occluder or normal suppression insures monocular vision.

In general, the fitting of telescopes to be used binocularly requires exact measurements, and the adjustments of the finished units necessitate unusual care. These precautions always need to be taken as binocular telescopes are initially uncomfortable to wear, and difficult to keep in adjustment.

Appearance

All types of telescopic spectacles are far from being cosmetically attractive. However, in the writer's judgment, the all-glass telescopic units are the least objectionable. This follows from the fact that half of the unit is recessed into the carrier lens. When the latter is mounted into a standard metal frame, the appearance is not greatly different from that of regular spectacles, Figure 7.

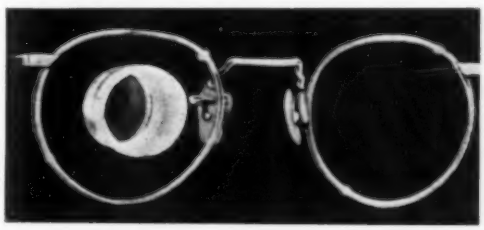

Figure 7. Distance unit.

D. PSYCHOLOGICAL FACTORS

It has been repeatedly pointed out in the literature that there are numerous psychological problems with which individuals with subnormal vision are burdened.[2, 4, 7, 8] These problems are principally responsible for the lack of cooperation and resistance which are frequently encountered when one attempts to improve subnormal vision by means of any type of magnifying unit. What are these psychological factors? In order to understand them, it is necessary to consider the cases of subnormal vision from the point of view of recency of onset or the duration of their subnormal vision.

Feinbloom, who has made a careful study of this problem, contends that the cases naturally fall into three groups.[3] The first group consists of those whose subnormal vision has been recently acquired. The second group is composed of those who originally had good vision but have had poor vision for a long time—five, 10 or 15 years. The third group is made up of those born with subnormal vision or of those who have acquired it at an early age.

Many of the patients in the first group are so concerned with the possibility of imminent blindness, although their pathology has cleared up and the visual acuity is stationary, that it is impossible for them to be concerned with anything that improves their vision but does not cure their eyes. In the second group are found many patients who have developed such complacency and have so satisfactorily adapted themselves that they resist any attempt at change in their vision. The third group consists of those who were born with their anomaly or who have acquired it early in life. Most of these cases can be divided into two classes. One, those cases who have attended schools for the blind and have acquired the emotional pattern and the psychological attitudes of the blind; and second, those who have acquired visual instructions by themselves and have crudely learned to cope with their anomaly. The latter eagerly seek any visual aid that can be supplied them. Usually those who have been trained as blind people do not seek further aid; nor do they readily accept any visual aid when it is offered.

The importance of these psychological factors becomes evident when they are considered together with the findings of an extensive investigation which has been made regarding motivation and visual defects.[10] The findings clearly indicate that the particular motivational pattern of the individual is the principal factor that determines the nature of the individual's adjustment to his visual defects or their correction. Each individual appears to respond to his visual difficulty in a

way consistent with his prevailing mode of adjustment. All evidence indicates that the visual condition cannot be considered apart from the notivational structure.

Due to this causal relationship between an individual's adjustment to his visual defect and the correction, some individuals with subnormal vision cannot be given satisfactory aid. Others, however, who have a strong motivation to improve their vision are greatly benefited.

Spatial Relationships

One of the problems that may arise after telescopic spectacles have been fitted is that of readjustment to normal spatial relationships. Because the field of vision is necessarily constricted, many monocular signs are no longer applicable, and recognition must be re-established on the basis of the new ocular pattern.

The use of a simple reading card device is quite helpful in teaching the patient to read. A black card, 3 in. x 5 in. with a slot cut out the width of the printing matter, on a normal sized book page and two lines deep will suffice as an excellent guide. Because of the parallactic displacement encountered in even slow head movements, it is easy to lose the printed line, thus causing annoyance and discouragement on the part of the patient. The reading card described will help immeasurably to train the patient to read.* Ordinary visual training methods apply here and have proved successful.

Another spatial factor is that induced by the parallactic displacement brought about by the afocal system of the telescope. This effect is familiar to all who have used a binocular or a telescope, and who have moved it rapidly in an arc from one object to another. "Against motion" is apparent, and to one attempting to initially use a telescopic spectacle, this motion may prove to be a source of confusion.

E. SELECTED CASE STUDIES

It might be well, in closing, to add a case history or two so that the clinical efficacy might be evaluated.

No. 1—Patient E.S.D., male, 39, occupation—salesman.

History—Has had poor vision since birth. Glasses of no help.

*Freeman has suggested the use of a movable table to hold reading matter. His experience has indicated that it is more difficult for a subnormal to learn to read by moving his head. The movable table permits the patient to hold his head in one position while moving the reading matter. Details of this table will be furnished at a later date.

This matter appears to be controversial in that Feinbloom and Pine have both found that the writer's suggested method, i.e., moving the head, is more satisfactory during the learning period.

Can see moving objects better than stationary. Father and paternal grandfather had same condition. Seems to see better at dusk.

Examination—Ophthalmoscope revealed disc to be extremely pale. Fundus otherwise negative. Media clear. Diagnosis: optic atrophy.

Uncorrected V. A. O.D. Fingers 15″
Uncorrected V. A. O.S. Fingers 15″

No improvement with ophthalmic lenses. With 1.8X telescopes patient had 20/100 vision in each eye and with a plus 8.00 add could read J2 type.

Fitted with Tait-Neill telescopes 1.87X and plus 8.00 add each eye. Binocular telescopic vision for near and far was obtained. With this device worn constantly, he was able to drive his car and carry on normal activities.

Subsequently, the patient was fitted with a pair of 2X Univis telescopes with an add of plus 5.00 permanently attached to each scope. The scopes were angled for the near focal distance and the patient obtained binocular near vision with them. He continued to use the Tait-Neill telescope for general wear and to use the Univis telescopes for desk work.

It is interesting to note that binocular vision was obtained at near in this case. This is not the usual situation, however.

No. 2—Patient A.C.H., male, 83, retired merchant.

History—Was able to read with regular glasses until 2 or 3 years ago. Both distance and near vision have failed to a point where he no longer read or recognized people across the street.

Examination—Impossible to see fundus clearly because of cataracts in each eye. Patient's age and physical condition were such that an operation is not advisable.

Uncorrected V. A. O.D. 20/300
Uncorrected V. A. O.S. 20/300

Only slight improvement in V. A. with ordinary ophthalmic lenses.

With Univis telescopes:

O.D. —2.00D. sph. ⌒ 2X telescope = 20/50 —2
O.S. —3.00D. sph. ⌒ 2X telescope = 20/40 —2

With this correction, the patient was able to resume normal activities. He used the peripheral field for walking about and the distance telescopes for motion pictures, church and reading signs, etc.

A reading add of plus 4.00 was provided to be used alternately on either eye.

No. 3—Patient H.J., male, 25, occupation—salesman.

History—Patient was an instrument delivered baby and had been wearing glasses since the age of six. His main complaint at the time of examination was his inability to see well for distance and near, and tiring of eyes on attempting to see for close work.

Examination—Patient was found to be a well developed male, 25-years-old, having a congenital searching nystagmus. Vision in the right eye 15/200 and in the left eye 10/200. With correction, right eye 20/200 and in the left eye 20/200 and J #6. Refraction under homatropine cycloplegia was:

O.D. —9.00D. sph. ⌒ —1.00D. cyl. × 155
O.S. —9.00D. sph. ⌒ —2.50D. cyl. × 35
= V. A. 20/100 —1

With a basic telescopic lens bilateral, the patient could read 20/50 —1 and by adding a 6 magnification lens to the basic telescopic lens, the patient could read J #2 at six inches.

The patient had been wearing the telescopic lenses together with a contact lens and had been able to carry on his occupation as a salesman during the day, and to attend school in the evening. Fundus examination revealed a myopic choroiditis with myopic crescents and an angiomatosis of the retina similar to those seen in phakomatosis.

The patient has been seen regularly and he is doing a very fine job of obtaining binocular vision. Also, the eyes have straightened themselves out and we have had to change the pupillary distance. He had a slight divergence at all times and a pronounced divergence under certain conditions.

The most interesting thing in this case, however, was the patient's changed personality and attitude in life. Unquestionably, the telescopic lenses did a major job in helping to rehabilitate this patient.

This patient was under the care of Dr. I. A. Abrahamson, ophthalmologist of Cincinnati.

Credit must be given to Dr. V. J. Ellerbrock, School of Optometry, The Ohio State University, and Dr. John C. Neill, Pennsylvania State College of Optometry, who supplied two of the case histories.

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Author's Abstract. Factors Concerning the Prescription and Use of Telescopic Spectacles.

A detailed study has been made of the following factors concerning the prescription and use of telescopic spectacles, combined with a study of three selected case histories.

The paper highlights the important problems involved in this little known type of lens device and gives the practitioner detailed information on the equipment necessary and methods employed in the examination and fitting of telescopic spectacles.

An extensive bibliography is attached, and for the first time a complete summary of the major factors concerning telescopic lenses and their application is presented in one paper.

Special attention is given the psychological factors, since the adaptation to a completely different optical system than the eye has been used to presents new and different problems.

Design and optical factors are discussed to give the practitioner an idea of the optical limitations imposed upon the lens designer due to the peculiar nature of the problem.—Roy Marks.

ABSTRACT

PALPEBRAL PTOSIS. O. R. Engelmann. Illinois Optometrist. 5. 3. 28-29. 1947.

A ptosis crutch is an attachment to a pair of spectacles designed to elevate the upper lid when the muscles of the lid fail to function.

A modification of the Neill ptosis crutch[1] is described by the author. This newly-designed crutch supports the lid by means of the spring action of the metal crutch which is covered with rubber. The author, in prescribing this crutch, does not make a plaster cast of the face as does Neill but rather shapes the crutch to the patient's lid by bending a lead wire which when completed becomes the model for the finished product which is made of gold wire. The Engelmann ptosis crutch may be attached to metal or plastic frames.

C. C. K.

1. J. R. Neill. Ptosis Crutches and Facial Masks. Amer. Jour. Optom. 10. 4. 116-129. 1933.

THE ACCOMMODATIVE RANGE THROUGH THE NEAR CORRECTION*‡

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INTRODUCTION

In the course of several discussions with practicing optometrists the writer has become aware of the extensive use of a test that has received little attention in the clinical literature. Those who have used the test quite generally acclaim its usefulness.

There seems to be in general use no simple name to identify the procedure or the finding. In a perusal of a number of commercially available refraction record forms and of several privately printed forms the writer has not found any provision for recording the results of such a test.

The descriptions given by the practitioners show a remarkable uniformity of procedure. With the tentative near correction in place, the patient is merely asked to move a test object alternately toward and away from his eyes to determine the limits of the range within which he sees "satisfactorily." The tentative near correction is then varied to produce changes in the position and length of the range that seem desirable.

The test object is often selected as one that may be particularly familiar to the patient, such as a needle-and-thread, a hand of playing cards, a sheet of music, a newspaper or a telephone book, or it may be a more-or-less uniformly used near-acuity test card. Many optometrists recommend mounting the tentative near correction in a spectacle-type trial frame to allow the patient greater freedom of head movement. The test object is usually held by the patient himself in both hands to permit him to "explore" the range for a minute or two. If the patient finds difficulty in carrying out the instructions or in appreciating the existence of a "range," the examiner may guide the test object manually, that is, by gently pushing the hands toward the patient's face until he indicates dissatisfaction with the blurredness or other

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‡Authors' Abstract, page 285.

symptoms produced, and then guiding the test object away until the patient again indicates dissatisfaction. The criterion for "unsatisfactory" or "inadequate" vision in this test is ordinarily not defined for the patient, but rather the patient selects his own criterion. Only if the patient displays considerable indecision does the examiner ordinarily resort to specific instructions or to more objective indications, such as inability to read a given size of letter.

It seems unlikely to the writer that the criterion ordinarily selected by the patient is anything other than a simple blurredness. The purpose of the test seems so apparent to most patients that a maximum performance is almost invariably elicited without prodding or coaching.

The origin, the widespread use and the popularity of the test probably are all related to the fact that when patients are fitted with new near corrections they often make exploratory observations of this type on their own initiative independent of the instructions and procedure incidental to the examination itself. Hence the refractionist who employs the procedure as a routine test merely formalizes that which the patient would ordinarily do anyhow.

The procedure received some theoretical consideration in Donders'[1,2] writings in 1864 insofar as he identified the accommodation measurements made in this manner as "binocular," to be distinguished from two other types of measurement, the "absolute" and the "relative." In a more general sense all three types were of course *binocular*, in that both eyes were used.

PURPOSES OF THE TEST

The purposes of the test are variously stated, and may be categorized as follows:

1. *As a practical demonstration to elicit pertinent comments concerning the adequacy of the range of clear vision attained through the tentative near correction.* The justification for this lies in the frequent failure of the case history to bring out salient points concerning the patient's visual needs. This very practical demonstration often reminds the patient of a number of special seeing problems that he would not otherwise realize to be different from an ordinary run of difficulties typically cited in the case history.

2. *As a practical demonstration of the optical limitations to be anticipated in the new correction, and therefore as an advisory aid relative to the instructions regarding the use of the new correction.*

3. *As an additional diagnostic or confirmatory set of findings*

relative to the accommodation and convergence faculties and their interrelationships. This is one of the purposes for which Donders employed the test. The possible interpretations are discussed below.

4. *As a method of establishing "tolerances" anterior to and posterior to the point of regard.* In this sense the test is often referred to as a "balancing" technique, but the procedures and rules of thumb actually employed do not represent a simple equalizing of quantities as suggested by this expression. The establishment of tolerances anterior to and posterior to the point of regard represents an attempt to cope with probable and possible variations in fixation distances with respect to the specific fixation distances assumed for purposes of computing a prescription formula.

METHODS FOR RECORDING RESULTS

The multiple purpose of the test gives rise to a question as to the most suitable method of recording the results of the test. Each of the following may be considered to have some merit as a method of recording the desired information on a clinical record sheet:

1. A specifically labeled space may be incorporated in the record sheet to permit a check mark ($\surd$), or other notations such as "O.K.," "?," "limited," etc., to indicate that the test had actually been made and that the results had been noted; some other symbol such as a colored check mark or the encirclement of the finding might then be used to indicate that this finding was used as a final criterion in the selection of an add.

2. Spaces may be incorporated in the record sheet to provide a quantitative entry of the position of the limits of the range through a tentative near correction. These might be identified as "P.P.—— and P.R.—— (through the tentative correction)." Such a specification could be recorded in centimeters from the spectacle plane.

3. A space may be provided for entering the add value which produces the range chosen by the patient as most satisfactory.

4. Spaces may be provided for entering the centimeters of tolerance posterior to and anterior to the assumed fixation distance. For example, if the lens add is intended for use at 40 cm. and the range is from 25 cm. to 60 cm., the tolerances may be entered as "Posterior: *15 cm.*, Anterior: *20 cm.*," measurements being taken from the basic reading card position of 40 cm.

5. A graphical representation of the finding may be made by plotting the limits on a diagram of the type shown in Figure 1.

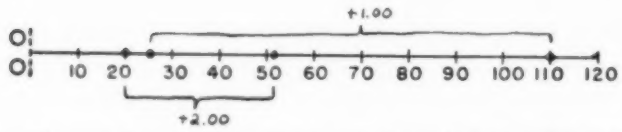

Figure 1. Diagram for recording the range through a tentative add. The scale is in centimeters along the primary sagittal line. The vertical dashed line represents the spectacle plane. The circles represent sample entries for a subject tested through tentative adds of +1.00 and +2.00.

6. Another graphical representation of the finding may be made by plotting the limits on an accommodation-convergence graph of the type described by Fry[3], as illustrated in Figure 2.

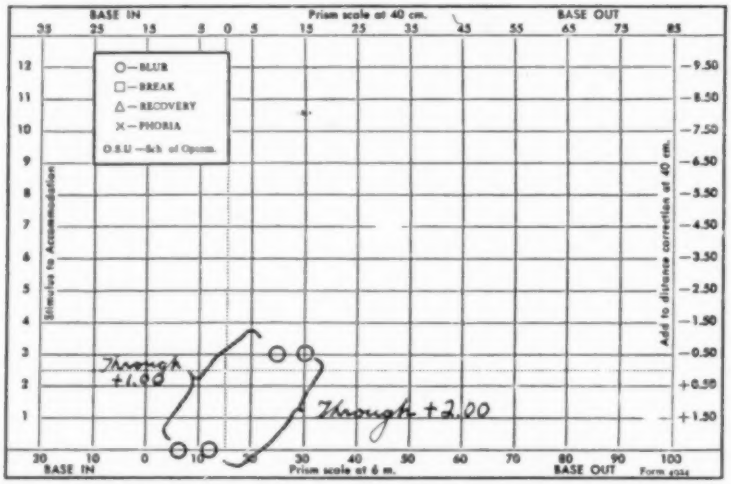

Figure 2. Graph for plotting accommodation and convergence findings. The abscissa values of the plotted points are represented in terms of the prism scale equivalents.

ANALYTICAL INTERPRETATIONS

Whatever interpretation can be made from this test lies for the most part in the relationship between accommodation and convergence, since both of these functions are involved. If it is assumed that blurredness is the criterion which the patient employs in establishing the limits of the range, then the two points of blurring represent simply two points at the boundary of the *zone of clear single binocular vision* previously described by the writer.[4] A graphical representation of this zone is given in Figure 3. The points of blurring, as plotted in Figure 2, are to be considered simply as points along the boundary of the zone, and to this extent are useful aids in establishing the characteristics of the zone for a given patient.

Insofar as the fundamental variables in the relationship between

accommodation and convergence as listed by Fry[3] can be represented in the parallelogram-characteristics of the zone of clear single binocular

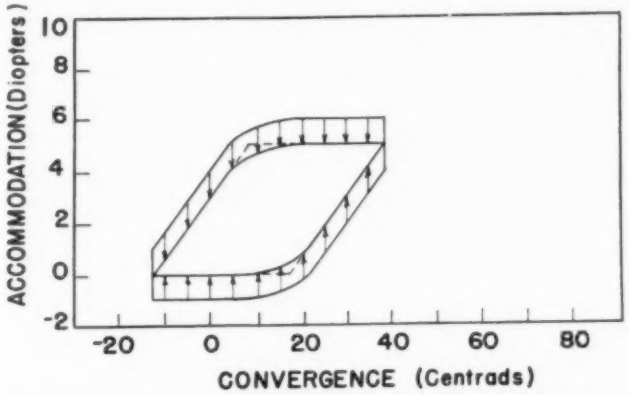

Figure 3. Schematic representation of the *zone of clear single binocular vision.*[4] The outer boundary circumscribes the zone as mapped out by haploscopic or other clinical procedures using blurredness as a criterion. The arrows represent an assumed correction of one diopter for the depth of focus, i.e., a subtraction of one diopter at points where the subject over-accommodated and an addition of one diopter at points where the subject under-accommodated. The resultant inner zone then represents the zone of play between accommodation and convergence, to be distinguished from the zone of clear single binocular vision included by the outer boundaries.

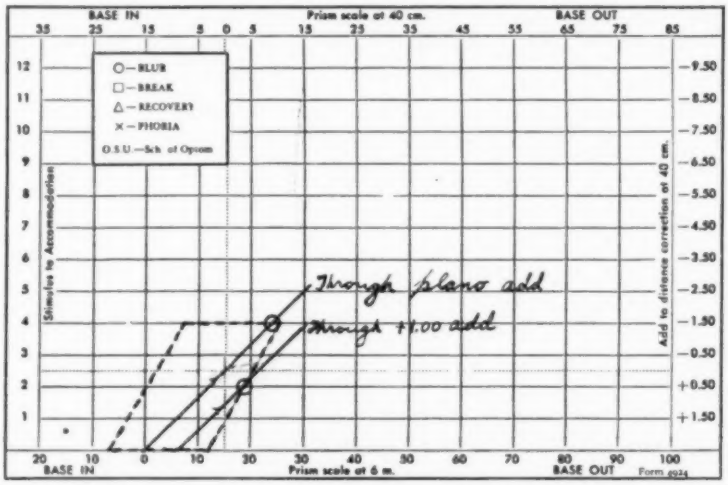
BASE IN
Prism scale at 40 cm.
BASE OUT
35 25 15 5 0 5 15 25 35 45 55 65 75 85
O—BLUR
□—BREAK
△—RECOVERY
×—PHORIA
O.S.U.—Sch. of Optom.
Stimulus to Accommodation
Add to distance correction at 40 cm.
12 11 10 9 8 7 6 5 4 3 2 1
−9.50 −8.50 −7.50 −6.50 −5.50 −4.50 −3.50 −2.50 −1.50 −0.50 +0.50 +1.50
Through plano add
Through +1.00 add
20 10 0 10 20 30 40 50 60 70 80 90 100
BASE IN
Prism scale at 6 m.
BASE OUT
Form 6024

Figure 4. Relationship of the binocular *near-point* blur to the zone of clear single binocular vision. The blurs are represented by circles, and the zone of clear single binocular vision is represented by the parallelogram. The solid oblique lines with arrows represent the stimulus-to-accommodation and simultaneously the convergence values in simple binocular push-up tests through a plano add and through a +1.00 add, as indicated. To simplify the analysis no allowance has been made for the depth of focus.

vision, the interpretation of the range findings described in this paper depends on a determination of the part of the zone boundary intercepted in producing a blur. With respect to the *near-point* blur a number of possibilities are illustrated in Figures 4, 5 and 6; with respect to the *far-point* blur a number of possibilities are illustrated in Figures 7, 8 and 9.

The case represented in Figure 4 would show a *near-point* blur at 25 cm. through the distance correction and a *near-point* blur at 33 cm.

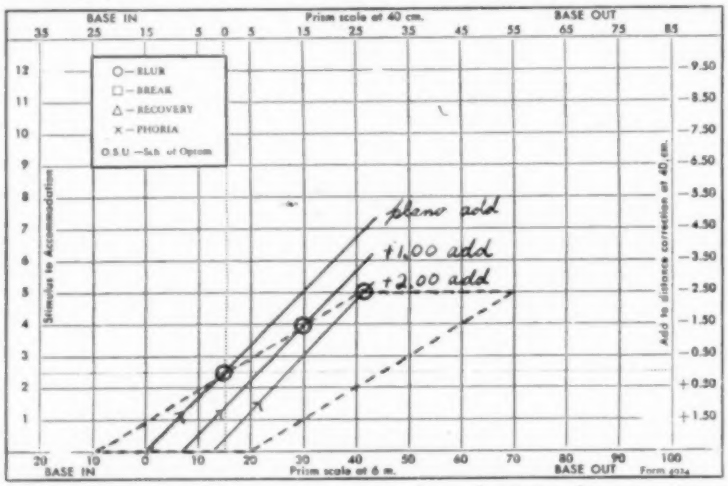
BASE IN
Prism scale at 40 cm.
BASE OUT
35 25 15 5 0 5 15 25 35 45 55 65 75 85
O — BLUR
□ — BREAK
△ — RECOVERY
× — PHORIA
O.S.U. — Sch. of Optom.
Stimulus to Accommodation
Add to distance correction at 40 cm.
plano add
+1.00 add
+2.00 add
12 11 10 9 8 7 6 5 4 3 2 1
−9.50 −8.50 −7.50 −6.50 −5.50 −4.50 −3.50 −2.50 −1.50 −0.50 +0.50 +1.50
20 10 0 10 20 30 40 50 60 70 80 90 100
BASE IN
Prism scale at 6 m.
BASE OUT
Form 4034

Figure 5. Example of *near-point* blurs determined by factors other than the amplitude of accommodation.

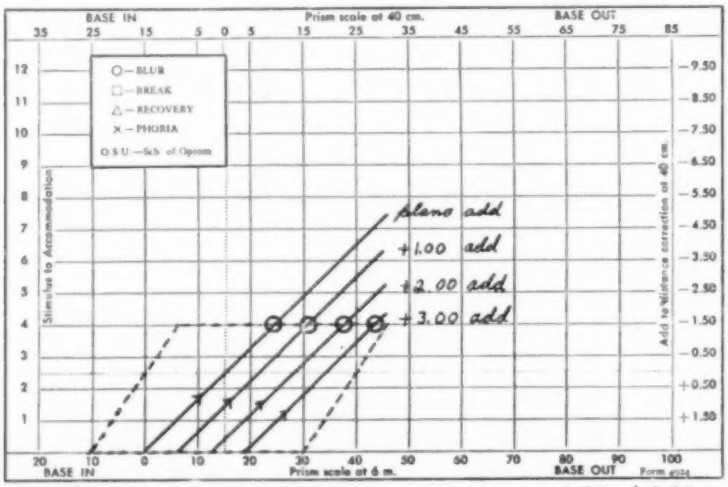
BASE IN
Prism scale at 40 cm.
BASE OUT
35 25 15 5 0 5 15 25 35 45 55 65 75 85
O — BLUR
□ — BREAK
△ — RECOVERY
× — PHORIA
O.S.U. — Sch. of Optom.
Stimulus to Accommodation
Add to distance correction at 40 cm.
plano add
+1.00 add
+2.00 add
+3.00 add
12 11 10 9 8 7 6 5 4 3 2 1
−9.50 −8.50 −7.50 −6.50 −5.50 −4.50 −3.50 −2.50 −1.50 −0.50 +0.50 +1.50
20 10 0 10 20 30 40 50 60 70 80 90 100
BASE IN
Prism scale at 6 m.
BASE OUT
Form 4034

Figure 6. Examples of *near-point* blurs through plano, +1.00, +2.00 and +3.00 adds limited by the accommodative amplitude only.

through a +1.00 add. This apparently paradoxical effect can actually be elicited in the case of a person having the particular combination of ACA ratio, positive fusional convergence, accommodative amplitude and basic phoria value represented by the parallelogram. In such an instance the blur at 25 cm. would represent the limit of positive fusional convergence, corresponding to a base-out-to-blur finding, while the 33 cm. blur would represent the maximum limit of the accommodation. This

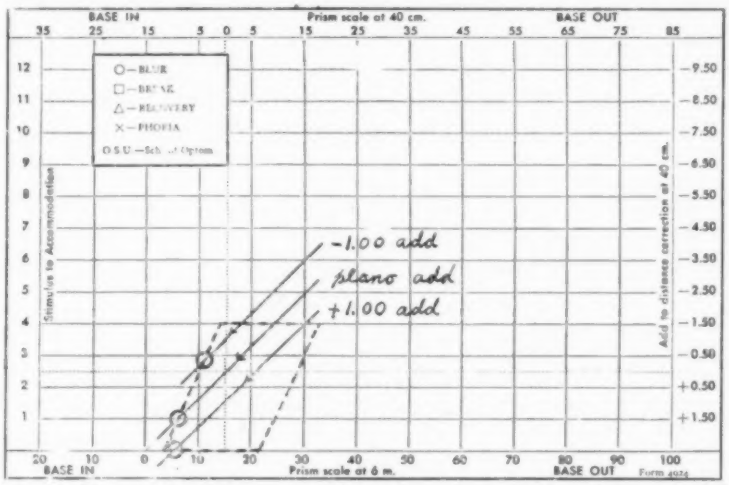

Figure 7. Examples of *far-point* blurs through —1.00, plano and +1.00 adds determined by factors other than the zero level of accommodation.

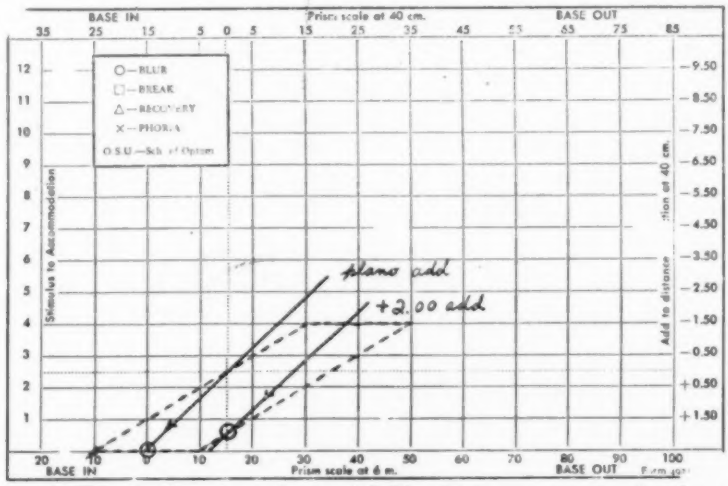

Figure 8. The finding through the +2.00 add is an example of a *far-point* blur limited by the range of positive fusional convergence. The finding through the plano add is limited by the zero level of accommodation.

interpretation in an instance in which the writer observed this apparently paradoxical effect was readily confirmed by the fact that a small amount of base-in prism brought the 33 cm. blur-point to 20 cm., which is

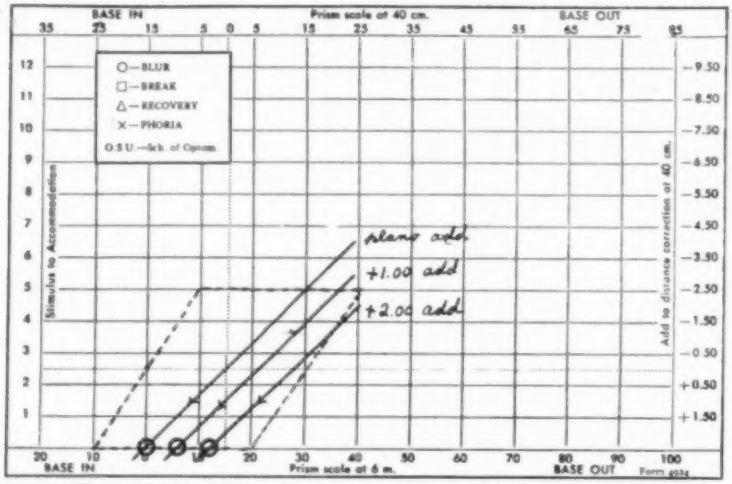

Figure 9. Example in which the *far-points* through various adds are limited only by the zero level of accommodation.

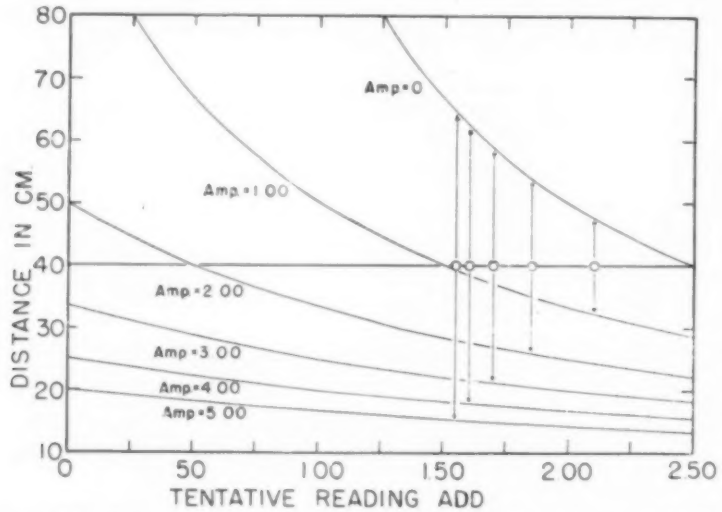

Figure 10. Theoretical *far-points* and *near-points* for various adds and various amplitudes. Each of the curves represents the *near-points* for a separate add. as indicated. The uppermost curve also represents the *far-points* for all adds. The horizontal line represents the arbitrary reading distance of 40 cm. The circles represent the adds for various amplitudes which place the "midpoints" on the 40 cm. line.

the blur-point ordinarily expected through +1.00 lenses when the amplitude of accommodation is four diopters. It is of course obvious from the analysis that the possibility of this effect occurring in a routine testing situation would be very rare.

The case represented in Figure 5 would show a *near-point* blur at 40 cm. through a plano add, a blur at 20 cm. through a +1.00 add and a blur at 14 cm. through a +2.00 add. The limitations through the plano add and through the +1.00 add depend on the combination of a high ACA ratio (represented by the extreme slope of the zone) and a low negative fusional convergence. It can be readily computed and demonstrated that if only the amplitude of accommodation was involved the *near-points* would be instead at 20 cm., 17 cm. and 14 cm. respectively.

This apparent over-effect of a plus add is not as rare as the previous effect described. The phenomenon is more familiarly described as an apparently reduced binocular amplitude of accommodation. In such an instance the patient finds that he can demonstrate a higher push-up amplitude of accommodation if he closes or occludes one eye, or ignores the diplopia that sometimes occurs at this point. The phenomenon is often undetected by reason of the suppression of the diplopia that may occur at this point.

In Figure 6 are represented the conditions most commonly met with in the routine test. The low amplitude of 4.00 D. is selected in this figure to represent a patient approaching presbyopia, for it is in such cases that the test is most commonly employed. In the case represented, the *near-points* obtained through no add, +1.00, +2.00 and +3.00, would be 25 cm., 20 cm., 17 cm. and 14 cm. respectively, just as would be ordinarily expected on the basis of an amplitude of 4.00 D., since the amplitude in these instances is the only limiting factor.

The *far-point* blurs present theoretically possible effects comparable to those produced in the *near-point* blurs. In the case represented in Figure 7 the respective *far-point* blurs through a —1.00 add, a plano add and a +1.00 add would be at 57 cm., 100 cm. and 100 cm., thus giving the apparently paradoxical effect of a minus lens decreasing the distance of the *far-point* and a +1.00 not decreasing it. It would be extremely rare that this phenomenon would occur, however, because the necessary combination of conditions in the accommodation-convergence relationship that would produce it is rare. Also, the test is not routinely made through minus lenses. To demonstrate this minus-lens reversal effect in average individuals it would be necessary to select an uncor-

rected hyperope with an average ACA ratio, or to use minus lens of higher power.

In Figure 8 is shown an instance in which a +2.00 add would reduce the distance of the *far-point* by more than the amount that would be accounted for on the basis of the difference in lens power only. In this instance the plano add permits a *far-point* at infinity as would be ordinarily expected, but the +2.00 add draws the *far-point* up to 40 cm. instead of the otherwise expected distance of 50 cm. The frequency of occurrence of this phenomenon would be limited by the fact that relatively few people have so high an ACA ratio combined with a low positive fusional convergence range.

The usual situation is that represented in Figure 9 in which the *far-point* distance is reduced in direct accordance with the dioptric value of the add by reason of the fact that the zero level of accommodation is the only limiting factor. In this instance the plano add gives a *far-point* at infinity, +1.00 at 100 cm. and +2.00 at 50 cm.

In the several analyses made in Figures 4 to 9 no allowance has been made for the depth of focus or the influence of proximity on the accommodation. For all practical purposes the depth of focus for a given individual may be assumed to be constant and therefore will affect all findings by the same amount, leaving the relative effects quite demonstrable. In instances in which proximal accommodation is present these relationships are not so easy to demonstrate, perhaps because of the unpredictable amount of proximal accommodation in play during the various parts of the test.

The difficulty in using the range test as a "balancing" technique is made apparent in Figure 10. The curves in this figure are computed on the assumption that the amplitude of accommodation is the only limiting factor, as represented in the examples of Figures 6 and 9. As in the examples, no allowance is made for depth of focus or proximal accommodation. The ordinate values of the curves represent the theoretical distances of the *near-points* to be obtained through the various adds represented on the abscissa. The uppermost curve represents the *near-point* values for all adds when the amplitude is zero and at the same time represents the *far-point* values for all adds regardless of the amplitude. The abscissa values of the circles represent the adds that would be required to place the reading distance of 40 cm. in the center of the range. It is seen that the only point at which the procedure would represent a balance in the range would be in absolute presbyopia in which case the add would be 2.50 D. The impracticability of using this test directly

as a balancing technique is most apparent for the case with a 5.00 D. amplitude in which instance a + 1.62 D. add would be required. This amount of add for a case with 5.00 D. of amplitude is readily conceded as too great. This can only mean that those who purport to use this test as a "balancing" technique are making systematic allowances in all cases short of absolute presbyopia, the amount of the allowance apparently being derived from practical experience with many patients. To the writer's knowledge no rules-of-thumb for making proper allowances have been published which would aid the beginner wishing to use this procedure. To be at all practical and convenient for the beginner the desired ranges probably would have to be set up in tabular form. From this analysis it would seem that such tabulated values would best be obtained empirically.

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Author's Abstract. The Accommodative Range Through the Near Correction.

A descriptive discussion is made of the nature and apparent purposes of a commonly used optometric test, identified for the purpose of the article as the accommodative range through the near correction. It is assumed that blurredness is the essential criterion employed by the patient being tested, and that the employment of the test in a routine refraction merely formalizes a test which the lay patient would naturally make anyhow for the purpose of evaluating the correction. Several possible methods for recording the findings are described.

A variety of possible test findings are graphically analyzed in terms of the fundamental variables in the accommodation-convergence relationship. Certain occasionally apparent paradoxes such as the decrease in the distance of the far-point by the reduction of plus sphere and the increase in distance of the near-point by the increase of plus sphere are explained.—Henry W. Hofstetter.

INVESTIGATION OF THE VARIATION AND THE CORRELATION OF THE OPTICAL ELEMENTS OF HUMAN EYES*§

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PART II — CHAPTER II

INVESTIGATIONS

A. REVIEW OF THE MATERIAL

Regarding the subjects used in this investigation, it is completely impossible to obtain by selection a truly normally distributed sample; on the contrary, the subjects have to be chosen on a different basis.

This study is limited to the age group of from 20 to 35 years, at the lower limit in order to be certain that growth of the eye has been completed, and at the upper limit to eliminate those eyes which would show changes due to age (lens changes). It would appear that the lower limit is set too low, because as is well known many myopic eyes continue their growth after the twentieth year. However, this source of error is excluded because the cases to be considered here spent several years under the control of the eye clinic of the university hospital and were as constant as any that could be found.

The subjects belonged principally to three groups. First, we have those who were patients in the clinic just mentioned; second, colleagues and nurses; and third, officer candidates of the school for the army and air corps. The first group contained a significantly larger percentage of refractive anomalies than the average population while the last was considerably superior in this respect; so that the subjects, in spite of how they were chosen, form in totality a rather representative combination which will be discussed in relation to this analysis. The subjects consisted of 315 females and 685 males.

In choosing subjects, comprehension, calm temperament and visual

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*UPSALA 1946. Appelbergs Boktryckeri A.-B.

§The second of six chapters. The third will appear in the July issue.

acuity are important attributes to be estimated and weighed. A number of tests had to be given up because the subjects fell short of the requirements in one or more of these attributes. This was especially true of the cases with higher refractive errors where there is often reduced visual acuity, and judging from the last part of the test, a reduced intelligence as well. For these reasons the material contains no cases of excessive myopia.

Only one eye, the right, was examined because of the fatigue of the subjects, since an examination of both eyes would be too fatiguing. The restriction of the experiment to the right eye simplified the technique since it saved resetting the apparatus. In addition the X-ray apparatus for the measurement of axial length could be made more stable.

While astigmatic cases are usually excluded from statistical studies on spherical refractive errors, they are included here. Such exclusion would have required the rejection of most cases of the higher refractive errors, since as has been frequently stated, high ametropia is often accompanied by astigmatism of higher or lower degree (Steiger and others). On the other hand, cases with decided oblique astigmatism (30° - 60°) were not included.

B. INVESTIGATION TECHNIQUE

The following tests were made:

1. Determination of the ocular static refraction.
2. Measurement of the maximum and minimum radii of the cornea.
3. Measurement of the depth of the anterior chamber.
4. Measurement of the length of the internal visual axis.
5. Ophthalmoscopic examination.

The techniques used shall be described. Discussion of the errors inherent in the investigation will follow later, along with estimation of the errors in the derived values. For the sake of uniformity, I, myself, made all these measurements.

1. THE STATIC REFRACTION was performed by Donders' method, using Granstrom's chart at a distance of 10 meters. Strict attention was paid to placing the test lens so that the distance from the vertex of its back surface to the corneal vertex was correct (12 mm.). In the case of strong lenses where a millimeter displacement was of importance, the distance was controlled with Wessely's keratometer. In the few cases where the lens could not be placed at the standard distance, the distance used was noted and was considered in computing the principal point refraction. Most subjects had been examined before in the eye clinic of the university hospital. A small number of cases in which Donders' tech-

nique did not appear reliable were controlled by skiascopy under homatropine by Rosengren's method.

2. THE CORNEAL RADIUS was measured on the keratometer of Javal-Schiotz (smaller model of Haag Striet). The apparatus was standardized by the use of steel balls of known radius. The radii in the meridia of the maximum and minimum curvatures were each measured four times.

3. THE DEPTH OF THE ANTERIOR CHAMBER was measured by the method of Lindstedt,[9] employing his original apparatus and following his directions. The apparatus was set up with a mechanical stage to make a more accurate adjustment possible. In each case 10 readings were taken.

4. THE LENGTH OF THE VISUAL AXIS was measured by Rushton's method. Its basis is that X-rays bring about the sensation of light in the dark adapted eye, a phenomenon that the earlier X-ray investigators reported (Rontgen, Brandes and Dorn, Crzellitzer, Himstedt and Nagel), and which faded into oblivion until Taft and Pirie each brought it back to life in 1932.[10] The method that Rushton published in 1938 was used for physiological measurements on several cases by Goldmann and Hagen in 1942.[11] As already stated in the foreword this method is a modification of the one applied to localizing foreign bodies in the orbit by Larsson and myself.

The principle of the method lies in directing a pencil of X-rays into the eye in a plane perpendicular to the optical axis. The X-rays cause an excitation of the retina of the dark adapted eye at their circular intersection, so that a dimly luminous ring is perceived. When the pencil of X-rays is shifted backwards, the perceived ring shrinks to a luminous point which occurs when the pencil reaches the posterior pole. It disappears completely when the pencil of X-rays falls behind the retina. Whether the X-rays cause the luminous phenomenon directly or by fluorescence is not known at this time.

a. APPARATUS (Figures 3 and 4). A specially built X-ray apparatus was used for these tests. The base is a slab of marble ½ x 1 m. in size, firmly fixed to the floor by two thick cement pillars. Two mechanical stages (Zeiss' mechanical stage apparatus) are tightly screwed to this base, one for the X-ray tube and one for accurate positioning of the subject.

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9. Lindstedt's method was chosen partly because the apparatus was available, and partly because of the advantages offered as compared with other methods. Its weakness is the strong chromatic aberration of the image forming lens which makes positioning difficult. (Compare with Rosengren [b].)

10. A paper by Gifford and Barth treats this subject as well.

11. Recently Sorsby and O'Connor investigated a few cases using this method.

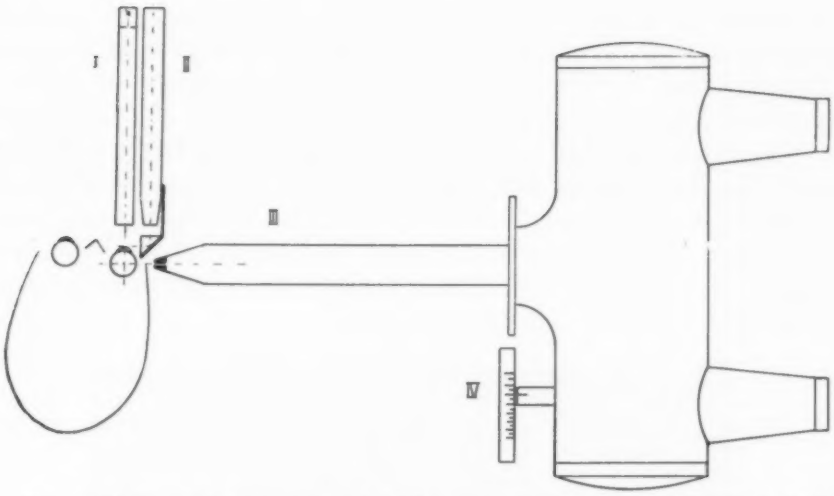

Fig. 3. Diagram of Arrangement for Measurement of the Axial Length. I. Sighting Arrangement. II. Magnifier with Right Angle Prism. III. Aperture Tube with Slit-shaped Diaphragm. IV. X-ray Tube with Millimeter Scale.

The X-ray tube is a half wave tube of type FAR 2 (firm of Schonander, Stockholm). In order to obtain a fully stable apparatus the original support was replaced by a firmer one which did not permit vertical displacement. The primary diaphragm was replaced with a brass tube of about 40 cm. length, lined with lead. The aperture was covered with a conical lead mouthpiece containing a vertical slit-shaped diaphragm, 3 cm. long and 0.1 mm. wide. The X-ray tube is so oriented that the aperture tube is horizontal and perpendicular to the direction of movement of the mechanical stage. Displacements in this direction never occur during the measurement; but the apparatus is so focused at the beginning that the slit is about 3.5 cm. from the eye being measured. The displacement of the tube in a perpendicular direction is observed by a millimeter scale with a vernier, placed on one of the mechanical stages. In order to insure more accurate readings, the scale is equipped with a magnifier and illuminator, both built into the equipment and screened off.

On the pillar of the other stage is a bite plate with some dental moulding material for impression of the teeth. By this means the best possible stabilization of the investigated eye is combined with its movement in any desired direction. A sighting device is attached to one side of the stage and a reading loupe to the other side. The sighting apparatus is directed parallel to the X-ray tube and consists of a small pinhole diaphragm in an opal glass plate dimly illuminated by a small lamp.

with crosshairs set a small distance away. Correction lenses, when needed, can be inserted at the proximal end of the sighting tube by means of a Rekoss disc of a Morton ophthalmoscope. The magnifier (about 10 X) is parallel to the sighting tube and is provided with a right angle prism through which observation of the corneal vertex is possible. The illumination for this is provided by a small lamp attached to the sighting tube by a ball and socket joint. After the adjustment, the subject turns on the lamp which projects light to the inner canthus. Since the investigation must be made in complete darkness, the lighting arrangement for recording the data has to be shielded.

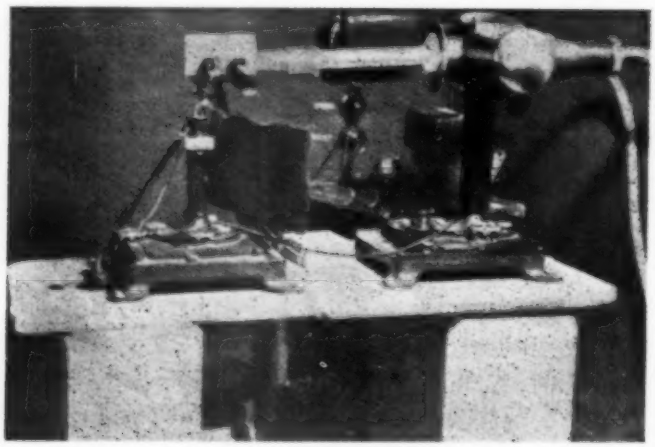

Fig. 4. Photograph of X-Ray Apparatus.

The calibration of the apparatus is accomplished by the use of a metal bar with a fluorescent surface, which is attached to the sighting tube. One end of the measuring bar is set at the midline of the scale of the magnifier. Then the X-ray tube is shifted so that the fluorescence ceases, at which time the X-ray tube beam is tangent to the other end of the bar and the position of the tube can be read off the scale on the mechanical stage. By means of this standardization, no consideration need be given to the thickness of the X-ray beam since the determining factor is its boundary. The position of the slit was checked daily.

THE PROCEDURE. After taking a dental impression and attaching the bite plate to the apparatus, the subject's head is adjusted by the examiner until it is in correct sighting position, and simultaneously the silhouette of the corneal vertex is accurately placed in the center of the scale of the magnifier. The focusing light and the corneal illumination

should be as dim as possible in order not to interfere with the observation of the X-ray phenomena. After this adjustment is completed the subject is released from the bite plate and dark adapted for at least 20 minutes. Then he is replaced in the apparatus and instructed to bite hard on the fixation plate so that the position of the eye is controlled, and when necessary, readjusted. The first adjustment should be made carefully by the examiner, in order to acquaint the subject with the procedure of the experiment.[12] Later the subject will move the X-ray tube himself, and after obtaining the correct position (of the X-ray tube), illuminate his cornea by pressing a button connected to the light. The position of the cornea and then the position of the X-ray tube can be read from the mechanical stages by the examiner. The first trial is intended as an example; after that at least six readings are taken, and if the variation is great, more readings are made.

In the experiment a potential of 70 kv. and a current of 8 ma. were used, which produced a clearly observable effect.[13] Each trial lasted about 15 to 30 seconds. The subjects were protected by lead spectacles and a lead screen.

In general it was not hard for the subjects to perceive the X-ray fluorescence. The greatest difficulty was in obtaining a sufficiently accurate fixation of the subjects' heads. In spite of the bite fixation some motion is unavoidable and many persons find it difficult to hold still sufficiently. This can be due in part to the complete darkness in which the test is conducted. Individuals with dentures must naturally be eliminated at the beginning. To minimize the effect of motion, the position of the cornea is read directly after the adjustment is completed. The ocular end of the magnifier is coated with luminous paint so that the examiner can keep his eye in the correct position in the dark. This enables him to make the reading as soon as the subject presses the button and illuminates his cornea.

5. OPHTHALMOSCOPY was undertaken to determine whether conus formation was present.

C. OPTICAL COMPUTATION METHODS

Although the optical elements were measured in both principal meridians,[14] only the one lying nearer the horizontal meridian was used.

12. To facilitate understanding of the experiment, the phenomenon can be illustrated for the subject. By using a projection lamp equipped with a ring-shaped diaphragm, a luminous ring can be projected on the wall and by movement of the projection lens this ring can be made to diminish.

13. Rushton used 72 kv. and 3 ma. which produced a rather dim visual sensation.

14. Both meridians were measured because in a future paper writer intends to correlate the astigmatism of the eye with that of the cornea and the lens.

Its value can be considered typical[15] because the vertical meridian is subject to relatively strong external influences (principally the varying pressure of the lids). The measurements obtained were used directly as data for the statistical treatment and also to derive the following values:

1. Refracting power of the cornea.
2. The principal point refraction.
3. Total refracting power of the eye.
4. Refracting power of the lens (anterior vertex refraction).

In the following discussion, the notation employed agrees for the most part with that of Berg (b) as is set forth in the following table.

TABLE 6

Element	Designation
Principal point of refraction	A
Reduced vergence of the fovea	B
Axial length	b_1
Radius of the cornea	ρ
Refracting power of the cornea	D_1
Depth of the anterior chamber	d
Anterior vertex refraction of the lens	D_2
Total refracting power of the eye	D
Refractive index of the aqueous and vitreous	n

1. THE REFRACTING POWER OF THE CORNEA was computed from the formula,

$$D_1 = (n-1) \cdot \frac{1}{\rho} \qquad \ldots\ldots\ldots(1)$$

The index of refraction used was 1.336, in conformity with Gullstrand's simplified schematic eye, and the difference between the indices of the cornea and the aqueous was neglected. (D_1 was obtained graphically).

2. THE PRINCIPAL POINT REFRACTION, as customarily used in optics and as used as a basis for the statistical work here, was computed from the following formula:

$$A = \frac{S'}{1 - \delta S'} \qquad \ldots\ldots\ldots(2)$$

where S' is the vertex refraction of the correction lens, and is the distance from the vertex of the back surface of the lens to the primary principal point of the eye. In general this equals 0.0135 m., when the distance of the lens from the anterior vertex of the cornea is 12mm., and the distance from the primary principal point to the corneal vertex is set at 1.5 mm. corresponding to Gullstrand's simplified schematic eye. In cases which

15. Steiger also used the horizontal value while Czellitzer used the more weakly refracting meridian.

departed from this value a correction was made if it was found necessary. The values were computed on a slide rule.

3. THE TOTAL REFRACTING POWER was computed in the following manner. From Gullstrand's formula

$$D = B - A \qquad \ldots\ldots\ldots (3)$$

we substitute for B, the value

$$\frac{n}{b_1 - d\left(1 - \frac{D_1}{D}\right)}$$

, and obtain

$$D = \frac{n}{b_1 - d\left(1 - \frac{D_1}{D}\right)} - A \qquad \ldots\ldots\ldots (3a)$$

which when solved for D becomes:

$$D = \frac{n - D_1 d - A(b_1 - d) + \sqrt{[n - D_1 d - A(b_1 - d)]^2 - 4D_1 dA(b_1 - d)}}{2(b_1 - d)} \qquad \ldots\ldots\ldots (4)$$

When A = O, i.e., for emmetropia, the solution becomes

$$D = \frac{n - D_1 d}{b_1 - d} \qquad \ldots\ldots\ldots (4a)^{16}$$

or, since

$$D_1 = \frac{n-1}{\rho},\ D = \frac{n(\rho - d) + d}{\rho(b_1 - d)} \qquad \ldots\ldots\ldots (4b)^{16}$$

Equation (4) is numerically quite difficult to handle so that in general the computations of controls were made nomographically; consequently the solutions were obtained graphically. A nomograph for the simultaneous solution of expressions $D_1 d$ and $n/(n - D_1 d)$ (see Equation 6), and for the computation of $A(b_1 - d)$ were employed. Proceeding from the obtained values, each of the expressions $[n - D_1 d - A(b_1 - d)]$ and $4D_1 dA(b_1 - d)$ were obtained from its own nomograph, and finally the square root expression was solved by its nomograph out of the last two values. The addition of the expressions $[n - D_1 d - A(b_1 - d)]$ and $\sqrt{[n - D_1 d - A(b_1 - d)]^2 - 4D_1 dA(b_1 - d)}$ and also the division by $2(b_1 - d)$ were performed on a computing machine.

By numerous control computations, it was established that the graphical solution introduced errors of not more than a few hundredths of a diopter, and in comparison with the errors of measurement, this is vanishingly small. The nomographic method offers the advantages of speed and clarity in the computation; the risk of large errors is virtually eliminated by its use.

4. THE REFRACTING POWER OF THE LENS was computed as if all the refraction occurred at the anterior pole, which is termed *the anterior vertex refraction.*

From the equation for the total refracting power of the eye

$$D = D_1 + D_2 - \frac{d}{n} D_1 D_2 \qquad \ldots\ldots\ldots (5)$$

we obtain an expression for the anterior vertex

16. Equations (4a) and (4b) were used in computation of their partial differentials.

refraction of the lens

$$D_2 = \frac{n(D - D_1)}{n - D_1 d} \qquad \ldots\ldots (6)^{17}$$

As said before, the expression $\frac{n}{n - D_1 d}$ was obtained from the same nomograph as $D_1 d$.

Because the positions of the principal points of the lens are unknown, one is compelled to introduce an approximation in the calculation. Either an assumed value for the distance from the anterior vertex of the lens to the optical center, or, as occurred here, the anterior vertex refraction can be used. Although the value for the refracting power obtained by the former method displays better agreement with the actual principal point refraction, my decision was to employ the anterior vertex refraction. This is lower in value than the principal point refraction, but the ranges of variation obtained by these methods differ insignificantly. This assumption also brings about a shift in the positions of the principal points of the total system with a resulting reduction in the value obtained for the total refracting power. When by the use of the partial differentials, $\frac{\delta D_2}{\delta d}$ and $\frac{\delta D}{\delta d}$ (as indicated in Tables 8 and 9), the values obtained from using the anterior vertex refraction are compared with those obtained by assuming the optical center of the lens to be 2 mm. behind the vertex, *our method gives values 1.5 D. lower for the total refracting power and 3 D. lower for the refracting power of the lens, but without significant difference in the range of variation of either function, nor in the coefficients of correlations. However, this factor of assumption should be borne in mind in making comparisons with the work of other researchers.*

D. THE ERRORS OF THE METHOD

1. THE ERRORS IN THE DETERMINATION OF THE REFRACTIVE ERROR are hard to estimate and it may be almost impossible to obtain an exact idea of their magnitude; therefore, two determinations by the same method were carried out. The literature contains no data on the size of the errors in a refraction by Donders' method, but Gullstrand indicates that it can be measured to within ¼ D. Holm has made a statistical comparison of the results of skiascopy and of Donders' method, and obtained an idea of the magnitude of the errors resulting from the use of both methods. He found a mean error of 0.2 D. His investigation is not

17. Calculation of the partial differential equation is obtained from Equation (6) by using Equations (1) and 4a. Details are omitted here.

entirely free of objections and his material cannot be compared with that discussed here. However, as has been contended, it is possible that the error in this text under favorable circumstances (large testing distance, exact positioning of the lenses, and subjects of appropriate age and with good acuity and comprehension) do not exceed ¼ D. This corresponds to a mean error of about ±0.1 D. A systematic error of +0.1 D. is introduced because the testing distance is 10 meters instead of infinity.

2. THE RADIUS OF THE CORNEA. The error of the apparatus was determined by the use of steel balls with exact and known radii (Berg, a). The result is given in Table 7.

TABLE 7

Radius of the ball	6.747	7.144	7.541	7.939	8.334	8.731
Average—six readings	6.738	7.143	5.537	7.938	8.322	8.730
Difference	0.009	0.001	0.004	0.001	0.012	0.001

The differences lie wholly within the limits of the error of measurement (see below), but they are all in the same direction which indicates that the obtained values are too small. This systematic error is less than —0.01 mm. and can be ignored.

The standard deviation $\sigma\rho$[18] is computed as ±0.012 mm. and the mean error obtained from the average of four readings is ±0.007 mm. The control on the mean errors were made on several days, with six sets of control measurements being made, and between the means in each set, the following differences were obtained: 0.01, 0.01, 0.003, 0.01, 0.02 and 0.01. This is completely compatible with the values above.

3. THE DEPTH OF THE ANTERIOR CHAMBER. Following Lindstedt, control measurements on an artificial anterior chamber were made and the error of the instrument was found to be less than —0.03 mm.

The mean error was computed by Equations (7) and (8). This gave $\sigma d = \pm 0.061$, and as the error of the mean in 10 measurements, $\epsilon d = \pm 0.02$ mm.

Control measurements on six cases gave the following differences between the two mean values: 0.01, 0.16, 0.06, 0.01, 0.03 and 0.06 mm.

18. The standard deviation here, as that in the determinations of the depth of the chamber and the axial length, is computed on every tenth case by the formula of Arley-Buch.

$$\sigma \approx s = \frac{q}{\sqrt{f}} \qquad \ldots\ldots\ldots (7)$$

where q^2 is the sum of the squares of the errors and f the total number of degrees of freedom used. The error of the mean of n determinations is then

$$\epsilon = \frac{\sigma}{\sqrt{n-1}} \qquad \ldots\ldots\ldots (8)$$

Lindstedt holds the probable error[19] of the method to be 0.028 and Rosengren to be 0.03; these values are in agreement with those found here.

4. THE AXIAL LENGTH. The systematic error here occurs by virtue of the lack of a sharp limit of the X-ray bundle, but it is numerically smaller than ± 0.1 mm.

Here again, the average error was calculated from Equations (7) and (8). $A\sigma b_1 = \pm 0.15$ was obtained. The deviation of the mean on six determinations is $\epsilon b_1 = \pm 0.07$ mm. As mentioned, when a significant tendency for a widened range of results occurred (restless subjects ?), more than six determinations were undertaken, namely up to 14. By these means the uniform precision that would have occurred if all subjects required the same number of determinations was obtained.

Control measurements were made on six cases. The following differences were found between the first mean value and the second: 0.02, 0.01, 0.02, 0.02, 0.25 and 0.16 mm., which show good agreement with the values given above for the average errors.

Rushton states that the error of the method is less than 0.1 mm.: Goldman, less than 0.2 mm.

Although the phenomenon of collapse of the luminous ring is so manifest that no doubt can exist when the limit is at the posterior pole, verification in an enucleated eye is naturally of interest. This procedure was carried out in one case[20] in which the eye was enucleated because of a choroidal sarcoma in the anterior part of the fundus: the posterior pole was entirely normal. After the enucleation a small quantity of sodium chloride solution was injected so that the eyeball exhibited normal intraocular pressure as determined by palpation. Then the eye was laid on an X-ray film and was photographed. The measurements were made on the X-ray image in order that the deformation of the eyeball which might result from direct measurement would be avoided. The thickness of the sclera at the posterior pole was found to be 0.8 mm. The results compare as follows: 1. Axial length, measured in vivo by Rushton's method (average of nine determinations) = 24.2 mm. 2. Axial length measured after enucleation (scleral thickness = 0.8 mm.) = 24.3 mm.

5. THE REFRACTING POWER OF THE CORNEA.

The corneal refracting power is a function of the corneal radius

19. The probable error of single observation is 0.67σ.

20. Recently this has been verified by Sorsby and O'Connor who reported, "in the excised eye, the length of the anterior posterior diameter was identical with the value obtained by X-ray measurement."

and the index,[21] and the mean error of the first can be completely determined from the mean errors of the latter two, according to the equation:

$$\epsilon_{D_1} = \pm\sqrt{\left(\frac{\delta D_1}{\delta \rho} \cdot \epsilon \rho\right)^2 + \left(\frac{\delta D_1}{\delta n} \cdot \epsilon n\right)^2} \quad \ldots\ldots\ldots (9)$$

in which $\frac{\delta D_1}{\delta \rho}$ and $\frac{\delta D_1}{\delta n}$ signify the conventional partial differentiation with respect to ρ and n respectively.

Accordingly $\frac{\delta D_1}{\delta \rho} = -\frac{n-1}{\rho^2} \fallingdotseq 7000$, and $\frac{\delta D_1}{\delta n} = \frac{1}{\rho} \fallingdotseq 145$.

We have no sure measure of mean errors for the refractive index, but in many different investigations (Helmholtz; Hirschberg, cited by Helmholtz; Freytag; Hallauer and Schiotz), the greatest difference scarcely exceeds 0.003, so that without serious error we can assume that $\epsilon n = \pm 0.0005$. Therefore $\epsilon D_1 = \pm 0.09$ D.

In the calculation of the corneal refracting power we have introduced an approximation. We know that neither the radius of the posterior corneal surface, nor the difference between the indices of the corneal substance and the aqueous, nor the thickness of the cornea are the same from case to case. We have assumed that the medium behind the anterior corneal surface is homogeneous and of the same refractive index as the aqueous. It is difficult to obtain a definite concept of the systematic errors introduced by this approximation because the radius of the posterior corneal surface[22] is not known. An approximate value of the errors can be obtained by comparing the refracting powers of the posterior corneal surfaces of Gullstrand's schematic and simplified schematic eyes (radii of anterior surfaces of both corneas are 7.7 mm.). For the schematic eye the corneal system has a refracting power of 43.05 D., and for the simplified eye, 43.63 D. Accordingly our approximation is about 0.5 D. too high for the corneal refracting power. In comparison with this error, the other systematic errors in D_1 can be neglected.

6. THE TOTAL REFRACTING POWER OF THE EYE. Since the total refracting power, according to Equation (4), is calculated as a function of measured values together with the index, the mean error can be computed from the mean errors of the elements (ϵA, $\epsilon \rho$, etc.) with the help of the equation:

$$\epsilon_D = \pm\sqrt{\left(\frac{\delta D}{\delta A} \cdot \epsilon A\right)^2 + \left(\frac{\delta D}{\delta \rho} \cdot \epsilon \rho\right)^2 + \left(\frac{\delta D}{\delta d} \cdot \epsilon d\right)^2 + \left(\frac{\delta D}{\delta b_1} \cdot \epsilon b_1\right)^2 + \left(\frac{\delta D}{\delta n} \cdot \epsilon n\right)^2} \quad (10)$$

Without significant error this can be reduced by considering the case A = O, and the calculation of the partial differentials can be simpli-

21. In the graduation of ophthalmometers the value of 1.3375 is taken as a basis so that, from a practical point of view, a radius of 7.5 mm results in a refracting power of 45 D.

22. Studies were made on only a small number of cases (Tscherning, Gullstrand, Nordenson).

fied by Equations (4a) and (4b).[23] Table 8 lists the formulas for these partial differentials as well as their values when we assume mean values for the independent variables.[24]

TABLE 8

	$\frac{\delta D}{\delta A}$	$\frac{\delta D}{\delta \rho}$	$\frac{\delta D}{\delta d}$	$\frac{\delta D}{\delta b_1}$	$\frac{\delta D}{\delta n}$
Formula	$\frac{n + D_1 d}{D_1 d - n}$	$\frac{d\,(n-1)}{\rho^2\,(b_1-d)}$	$\frac{n-D_1 b_1}{(b_1-d)^2}$	$\frac{D_1 d - n}{(b_1-d)^2}$	$\frac{\rho - d}{\rho\,(b_1-d)}$
Numerical Value	—1.25	943	723	—2820	27
$\frac{\delta D}{\delta} \cdot \epsilon$	±0.125	± 0.007	± 0.014	± 0.197	± 0.014

By using the values of the table in Equation 10 we find that $\epsilon_D = \pm 0.23$ D.

The value for the total refracting power includes an error derived from systematic errors through their partial values. If we designate these systematic errors as $\triangle A$, $\triangle \rho$, etc., the resulting error for D is

$$\triangle_D = \frac{\delta D}{\delta A}.\triangle A + \frac{\delta D}{\delta \rho}\triangle \rho + \frac{\delta D}{\delta d}\triangle d + \frac{\delta D}{\delta b_1}.\triangle b_1 + \frac{\delta D}{\delta D_1}.\triangle D_1 \quad \ldots\ldots\ldots (11)$$

This last expression is related to the error arising from neglect of the posterior corneal surface. Since $\frac{\delta D}{\delta D_1} = -\frac{d}{b_1 - d} = -0.171$, the last expression is —0.085 D. Computed on this basis the systematic error of D is given as —0.52 D. at most.

7. THE REFRACTING POWER OF THE LENS. Since the refracting power of the lens is calculated as a function of the same magnitudes as those which underlie the computation of the total refracting power, its errors can be calculated similarly. The details of the computation will be omitted, and in Table 9 only the numerical values of the partial errors due to the measured or assumed elements are reproduced.

23. $\frac{\delta D}{\delta A}$ must naturally be calculated from Equation (4), after which A is set equal to 0.

24. $n = 1.336$, $\rho = 7.8$, $d = 3.5$ and $b_1 = 24.0$.

TABLE 9

$\frac{\delta D_2}{\delta A} \cdot \epsilon A$	$\frac{\delta D_2}{\delta \rho} \cdot \epsilon \rho$	$\frac{\delta D_2}{\delta d} \cdot \epsilon d$	$\frac{\delta D_2}{\delta b_1} \cdot \epsilon b_1$	$\frac{\delta D_2}{\delta n} \cdot \epsilon n$
± 0.141	± 0.049	± 0.028	± 0.223	± 0.052

The resulting error of the mean for D_2 is obtained from these partial differentials by a formula analogous to Table (10):

$$\epsilon D_2 = \pm 0.28 \text{ dptr.}$$

By a process comparable to that used for the total refracting power, we conclude that the highest systematic error for the refracting power of the lens is —1.21 D.

TABLE 10

Compilation of Experimental Errors

Element	Mean Error	Mean Error in % of Range (6)	Systematic Error (Maximum)
Princ. Pt. Refraction (A)	± 0.10D	0.6*	+ 0.1 D
Corneal Radius (ρ)	± 0.007 mm	0.5	— 0.01 mm
Depth Ant. Chamber (d)	± 0.02 mm	1.2	— 0.03 mm
Axial Length (b_1)	± 0.07 mm	0.8*	± 0.1 mm
Corneal Ref. Power (D_1)	± 0.09 D	1.1	+ 0.5 D
Total Ref. Power (D)	± 0.23 D	2.1	— 0.52 D
Lens Ref. Power (D_2)	± 0.28 D	3.3	— 1.21 D

*Because of the skewness of the principal point refraction and the axial length distributions, their ranges are each set equal to 8 σ.

[Part three of this paper will appear in the July issue.]

ABSTRACT

AN ANALYSIS OF CONTACT LENSES FITTED DURING 1947. R. K. Watson. The Optician. (London.) 115. Issue of January 30. pp. 7-8. 1948.

During 1947 the author prescribed contact lenses for 139 patients. Seventy of these were men, 69 women. The age groups of these patients follow: eight patients under 20 years; 87 patients, 20 to 30 years; 37 patients, 30 to 40 years, and seven patients over 40 years.

The reasons for requiring contact lenses are interesting. Sport is the chief incentive in 56 cases; alternative to spectacles in 40 cases; appearance in 18 cases; refused to wear spectacles in 7 cases and to improve visual acuity in 4 cases.

Progress reports indicate that 15 of the patients are very satisfied and wear their contact lenses most of each day; 39 others are able to use their lenses for about five hours each day.

V. H.

RETINITIS — A CASE REPORT*

Ralph E. Wick†
Rapid City, South Dakota

PATIENT: R.D.N., male, age 60.

OCCUPATION: Sheep rancher.

CHIEF COMPLAINT: Has noticed a sudden loss of vision in the left eye in the last few months. Reading still normal although things seem to blur at times.

HISTORY: Last eye examination three years ago. Reading glasses prescribed then by the writer. A brief summary from the records of three years ago follows:

COMPLAINT: Trouble in reading only. Distance vision good.

HISTORY: Has never worn glasses or had eyes examined. Used magnifying glasses only.

GENERAL HEALTH: Good, but has slight dizzy spells once in a while.

EXTERNAL EXAMINATION: Revealed nothing abnormal with the exception of poor teeth. Patient was advised to visit a dentist and if necessary have remaining teeth removed.

OPHTHALMOSCOPIC EXAMINATION: Media clear, disc well defined and vessels normal.

ANALYTICAL EXAMINATION:

O. D. —0.25 D. cyl. x100
O. S. **+0.25 D. sph.**

MUSCLE BALANCE: Generally satisfactory.

NEAR-POINT FINDINGS:

Fused cross-cylinder	+1.75 Add
Tolerance of accommodative stimulation	—.50
Tolerance of accommodative inhibition	+.75

Above findings through a +1.75 add.
Correction prescribed.

O. D. + 1.75 D. sph. ⊃ —0.25 D. cyl. axis 100
O. S. +2.00 D. sph.

The above prescription was made up in a reading correction only. Patient advised to see dentist and also to have a check-up by a physician to determine cause of dizzy spells.

GENERAL HEALTH: Physical condition seems normal but patient tires easily. Gets dizzy spells from overworking. Never had physical exam-

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†Optometrist. Fellow, American Academy of Optometry.

ination as he seems to feel all right most of the time. Teeth have been removed.

PRELIMINARY EXAMINATION:

Unaided visual acuity: O. D. 20/20. O. S. 20/80. O. U. 20/20.

External examination: Lid margins normal; slight conjunctival injection; cornea clear, pupillary reflexes direct and consensual, pupil size large and well defined. P.D. 66 mm.

Ophthalmoscope: Right eye—media clear; edge of disc slightly blurred, vessels show definite signs of arteriosclerosis, i.e., tortuosity of vessels with a break in the continuity of the veins wherever they are crossed by the arteries, fine white lines along the border of the arteries. Left eye—media clear, edge of disc slightly blurred, small retinal hemorrhages and definite signs of arteriosclerosis as listed above.

ANALYTICAL EXAMINATION:

Retinoscopy (static):	O. D. $+.25 \bigcirc -.25 \times 15$
	O. S. $+.25$
Subjective:	O. D. $-.37 \times 15$
	O. S. $+.25$
Visual Acuity (corrected):	O. D. 20/20
	O. S. 20/80
	O. U. 20/20
Muscle balance and near-point findings:	
Induced phoria:	ortho.
Vertical phoria:	ortho.
Near-point phoria:	8° exophoria
Binocular cross-cylinder:	$+2.25$
	$+2.25$
Amplitude of accommodation:	1 D
Tolerance of accommodative stimulation:	$-.50$
Tolerance of accommodative inhibition:	$+.75$

(Complete muscle balance findings not taken due to patient's age and pathological condition of eyes.)

DIAGNOSIS:

The loss of vision in the left eye, from 20/20 to 20/80, could not be accounted for by any change in refractive error and so it was assumed to be pathological.

The retinal hemorrhages and arteriosclerosis are definite symptoms of an increased hypertension throughout the circulatory system.

The examination was completed to be sure that the loss of vision was of pathological nature. The change in the distance correction was so small as to be of no consequence. The change in the near-point correction (an increase of +.50) was normal for the three-year period that had elapsed.

ADVICE TO PATIENT

The patient was advised to have a thorough physical examination at once. The patient had been advised three years previously to visit a physician to ascertain the cause of the dizzy spells he had at that time. This had not been done; so, with the patient's permission, the writer phoned and made an appointment with a local clinic for a thorough physical examination. As a result of the physical examination the patient was advised to quit work and to obtain several hours of rest each day. The patient informed us that it would be impossible for him to quit work entirely but that he would take it as easy as possible. The local clinic advised us that little could be done for the patient medically, but that rest periods were essential.

POST REFRACTION

Six months later, October 6, 1945, the patient again reported to the writer. He complained at that time of a considerable loss of vision at a distance and an inability to read. He had some dizzy spells but not enough to interfere with his work which he had reduced in part His vision checked 20/60 in the right eye and 20/100 in the left eye. The refractive error as revealed by the retinoscope was approximately the same as six months ago. No improvement could be made in the vision of either eye by any lens change. The ophthalmoscope revealed retinal hemorrhages in the macula area, tortuous vessels and a blurred disc.

Due to the sudden loss of vision in both eyes the patient was advised of the seriousness of his case and it was recommended that he visit the Mayo Clinic at Rochester, Minnesota, to see if anything could be done for his physical condition and thereby prevent complete loss of sight. A copy of the report received from Rochester follows:

His eyes were examined in the clinic on October 11 and 12. The vision of the right eye was recorded as 2/60, of the left eye 6/60. Ophthalmoscopic examination revealed advanced retinitis of hypertension and arteriosclerosis. The retinas of both eyes were markedly edematous and hemorrhagic. The retinal vessels were extensively sclerotic and had broken under the unusually high blood pressure.

As his visual damage is due entirely to his physical condition, it was not possible to afford him any medical relief.

The patient stopped at the writer's office on his way home from Rochester, Minnesota. He had been referred to a physician near his home and he will be under constant medical supervision from now on.

SUMMARY:

This case presents a progressive reduction of vision due to excessive arterial hypertension throughout the body. The patient was referred early for medical treatment. However, little benefit was obtained as a result of the examination as the patient was unable to follow the physician's advice. Apparently little other treatment could be undertaken due to his age. Further loss of vision warranted referring him to specialists at Mayo Clinic, but little permanent help was obtained. However, the patient was placed under medical care. Throughout the case the dominant symptom was loss of vision as the dizzy spells were never serious enough to bother the patient or interfere with his work.

WOOLWORTH BLDG.,
RAPID CITY, SOUTH DAKOTA

ABSTRACT

FACTS CONCERNING THE RE-ISSUANCE OF DRIVER'S LICENSES. L. C. Rosser. North Carolina Optometrist. 11. 6. 1-3. 1947.

The 1947 General Assembly of North Carolina passed a law which requires certain tests for persons who have to have their driver's license renewed or who wish to secure a license to drive a motor car for the first time. The requirements are that an applicant must take and pass (1) an eye test, (2) a highway sign test, (3) a driver's rule test, and (4) a road test.

The eye test is the usual visual acuity test at 6 M., a very simple color vision test and a test of the horizontal visual fields. These tests will be given applicants by lay examiners. Applicants who fail will be referred to optometrists and ophthalmologists for further visual attention.

The passing criteria under this new act are severe. Those applicants whose binocular vision falls below 20/30 will be rejected until vision is improved with glasses up to this point or better. If this is impossible, the examining optometrist or ophthalmologist must issue a statement to the effect that 20/30 visual accuity O. U. is impossible. Visual acuity of O. U. 20/60 or less will disqualify an applicant under the new regulations.

C. C. K.

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THE BASIC PRINCIPLES OF REFRACTION

The names Ketchum, Maybee, Needles, Ryer, Sheard, Wiseman and Woll conjure up a picture of progress in early optometric education. These are the men who, along with a handful of other scientists, laid the groundwork for an acceptable understanding of refractive science based upon known truths and principles fundamental to the survival of optometry.

The extent and importance of the work of this group was again brought home while I was browsing through my library the other day. There I ran across the monographs written by these men just 30 years ago. This set, which I had bound into one volume, contains the original *"Optometrical Course of Study,"* edited by Dr. William S. Todd and

published by the Department of Education of the American Optometric Association in 1919.[1]

While thumbing through this volume, I was again struck by the competence of these early optometric authors. Each monograph, now three decades old, is as well grounded in scientific truth as when it was first published. In fact, with only a few minor changes, all 15 could be reprinted today and serve the same useful purpose as they did in 1919 and 1920.

These authors owe no apologies for their works—another fact to their credit—for many writers eventually find themselves regretting what they've written or apologizing for certain viewpoints after their material appears in print. Papers sometimes turn up to plague the author many years after publication perhaps because the original paper was incomplete, or he has changed his views. The doubtful paper then trails the author through one bibliography after another. It is quoted and referred to by others and, at times, causes no end of explanations. Not so with these monographs. The facts presented by these writers are as true today as when first sent to the printers.

The publishing of this material was an outstanding accomplishment of the Department of Education of the American Optometric Association. Publication of the material was timely for optometry. The monographs were widely read and served their purpose for a decade, and constitute one of the great educational services of the A. O. A. Moreover, the ageless facts contained between their covers will do much towards enshrining these writers in the lasting history of optometry.

And going from the past to the present—these men, after laying the groundwork, continued to keep faith with their early responsibilities and have through the years advocated only scientifically tested refractive measures and techniques—the only way to continued progress in optometric science.

CAREL C. KOCH

1. Anatomy of the Orbit, M. B. Ketchum; Arithmetic, Algebra, Geometry and Trigonometry, H. D. Minchin; Ocular Muscles, W. B. Needles; General Anatomy, Physiology and Hygiene, F. A. Woll; Optical Shopwork, W. W. Slade; Refractive and Accommodative Errors and Their Correction by Subjective Methods, W. G. Maybee; Grinding of Ophthalmic Lenses, A. E. Surdam; Ophthalmometry, E. LeRoy Ryer; Practical Lessons in Blood Pressure Testing, E. G. Wiseman; Static and Dynamic Skiametry, and Ocular Accommodation, Charles Sheard.

CURRENT COMMENTS

Virginia Huck
Editorial Assistant

Optometrists will confer a favor by sending news items of general interest for this department: such as relate to new instruments, clinical techniques, education, visual health and optometric legislation and organization.

A NEW MAGAZINE, "PHYSICS TODAY."

A new magazine with a unique goal has come on the market. It is a magazine sponsored by the American Institute of Physics, and after reading the first issue, we can truthfully say that the editors have made a long stride toward their goal.

"Physics Today" is a 40-page publication for, and we quote their first editorial, "the physicist, to inform him in comfortable, everyday language, of what goes on, why and who goes where. But it is also for the chemist, the biologist and the engineer. . . . for the student, the teacher, the lawyer, the doctor and all who are curious about physics; it is for administrative officials . . . for editors and writers whose profession puts them midway between what is done and how it should be reported."

Which in short explains the purpose of this new venture: to inform in non-technical language both physicists and non-physicists about progress in the various fields of physics as it affects human activity.

The purpose is a worthy one, for there has been a wall of terminology for a time between scientists and lay persons, and any effort to break it down deserves support.

We recommend "Physics Today" for several reasons: it is informative; it is accurate and enjoyable reading. The first issue is of special interest to optometrists as one of the articles deals with color vision. The paper is a report on the 1947 International Conference on Color Vision at Cambridge, England, by David L. MacAdam, who attended the conference.

The official address of the new magazine is American Institute of Physics, 57 East 55th Street, New York, 22, New York.

NOTES ON STENSTROM'S PAPER

Dr. Solve Stenstrom's paper on measurement of the axial length of living eyes, which began serially in our May issue, is the second important German paper on refraction to be recently translated by an American optometrist. The first was Dr. Carl Radde's translation of Hering's "Spatial Sense and Movement of the Eye."

Dr. Stenstrom's manuscript, "Investigation of the Variation and the Correlation of the Optical Elements of Human Eyes," was first published in 1947 in Germany. Research on the project in 1946 was carried on at the University of Upsala.

Shortly after the paper was published in Germany, Columbia University decided to translate it, and translation was begun last year by Dr. Daniel Woolf under the supervision of Dr. C. L. Treleaven of the School of Optometry. Dr. Woolf is a faculty member at Columbia and a Fellow of the American Academy of Optometry.

American optometrists owe a debt of gratitude to Dr. Woolf, as Dr. Stenstrom's findings are of utmost importance to the science of refraction. By means of the X-ray, Dr. Stenstrom was able to measure the anterior-posterior diameter of the eye. He correlated this data with other factors affecting refractive findings, such as the index of refraction of the media, and curvatures of the cornea and lens, and recorded these findings in the paper now running in the Journal.

CHICAGO COLLEGE OF OPTOMETRY ACCREDITED

Initial approval of the recently-organized Chicago College of Optometry was issued by the American Optometric Association Council on Education and Professional Guidance on May 6. Technically, this means the college is accredited provisionally until it has graduated its first class. After completion of the four-year course by the first class, the Council will re-inspect the college for final approval.

The post of executive dean of the college has been accepted by Dr. Eugene Freeman, Chicago optometrist and educator. Dr. Freeman will serve as technical adviser and will supervise the academic functions of the college.

Dr. Ernest S. Takahashi, a graduate of the California School of Optometry, is dean of the college. The Chicago College of Optometry began operating last November in quarters formerly used by the Monroe College of Optometry.

PUBLIC HEALTH—HERE AND ABROAD

President Truman's conference on the health of the nation was held as scheduled in Washington, D. C. in May, but the results at the moment are obscure. Nearly 800 persons attended the conference at the President's request for the purpose of mapping out a tentative ten-year health program for the United States.

Judging from press releases to date, the conference did not even slightly resemble the "first step toward socialized medicine," as the

general public feared it might. President Truman's recommendation to the group that a compulsory sickness insurance system be adopted in the United States met with decided opposition from the majority of the medical profession. Reports from optometry's representative, Dr. Louis Kraskin, Washington, D. C., also indicate discussions at the conference, while interesting, were quite nebulous.

Abroad, the picture is different. On July 5, Great Britain will launch her greatly discussed National Health Service Plan. The role the optometrists of England will play in this scheme was described by William E. Hardy, British optometric editor, on May 12 in New York.

Speaking before the New York City Optometric Society, Mr. Hardy said that British optometrists will make about 80 per cent of the visual examinations.

Aneurin Bevan, British health minister, according to Mr. Hardy, has publicly announced that British optometrists will play an important professional role in the eye care service.

Mr. Hardy pointed out that British optometrists have been aided greatly by the scientific and clinical research of American optometrists, notably in contact lens research and in the treatment of squint.

According to reports from London, opposition from the British Medical Profession was overcome only recently—up to the last of May it appeared that success of the program would be jeopardized by opposition from over 90 per cent of professional men. On May 28, however, The British Medical Association representative body voted to advise the medical profession to join the Labor government's health program, which removed a possibility that the program would be blocked and get off to a crippled start.

ROCKY MOUNTAIN OPTOMETRISTS TO MEET

The Rocky Mountain Congress of Optometry for 1948 will be held in the Shirley-Savoy Hotel, Denver, Colorado July 25, 26, and 27.

ABSTRACT

TOBACCO AMBLYOPIA. E. Jackson. Canadian Journal of Optometry. March-April. 601-603. 1947.

The author presents a case report of a patient with a tobacco amblyopia. His uncorrected visual acuity was O. D. 20/400. O. S. 20/400. Corrected visual acuity. 20/200 O. S. 20/200. He was found to have the usual scotoma in each visual field. Patient used tobacco in cigar form constantly. Two weeks after giving up tobacco his visual acuity was O. D. 20/30. O. S. 20/20-1. and the visual fields were somewhat improved.

C. C. K.

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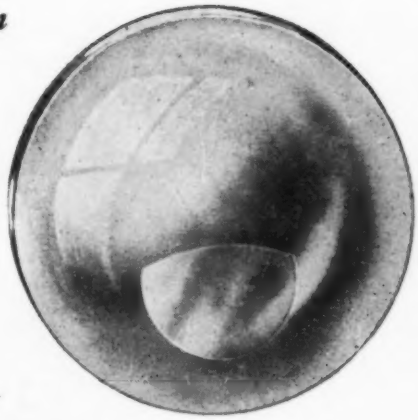

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